Drier Forest Composition Associated with Hydrologic Change in the Apalachicola River Floodplain, Florida

By Melanie R. Darst and Helen M. Light

Prepared in cooperation with the
Florida Department of Environmental Protection
Northwest Florida Water Management District

Scientific Investigations Report 2008-5062

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: *http://www.usgs.gov/pubprod*
Telephone: 1-888-ASK-USGS

For more information on the USGS--the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:

World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:

Darst, M.R., Light, H.M., 2008, Drier Forest Composition Associated with Hydrologic Change in the Apalachicola River Floodplain, Florida: U.S. Geological Survey Scientific Investigations Report 2008-5062, 81 p., plus 12 apps.

Contents

Figures

Tables

Conversion Factors, Acronyms, and Abbreviations

Multiply	By	To obtain
centimeter (cm)	3.3937	inch
centimeter per year (cm/yr)	0.3937	inch per year
meter (m)	3.281	foot
square meter (m^2)	10.76	square foot
cubic meter per second (m^3/s)	35.31	cubic foot per second
kilometer (km)	0.3861	mile
square kilometer (km^2)	0.3861	square mile
hectare (ha)	2.471	acre

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NGVD 1929).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Acronyms

ACF	Apalachicola/Chattahoochee/Flint (river basin)
ARQA	Apalachicola River Quality Assessment
FDEP	Florida Department of Environmental Protection
FI	Floodplain Index
FSC	Floodplain Species Category
GIS	Geographic Information System
GPS	Global Positioning System
NWFWMD	Northwest Florida Water Management District
NWS	National Weather Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Additional abbreviations

ba, basal area
dbh, diameter at breast height
Hiblh, high bottomland hardwood
Loblh, low bottomland hardwood
p, probability value
r, Pearson correlation coefficient
rba, relative basal area
rd, relative density
rm, river mile
sd, standard deviation
>, greater than
<, less than
≥, greater than or equal to
≤, less than or equal to

Study transect abbreviations

BLT, Blountstown
BR, Brickyard
CH, Chattahoochee
EA, EB, EC, Eichholz A, B, and C
MR, Muscogee Reach
OR, Old River
PL, Porter Lake
SE, Sweetwater
TO, Torreya
WEW, Wewahitchka

Drier Forest Composition Associated with Hydrologic Change in the Apalachicola River Floodplain, Florida

By Melanie R. Darst and Helen M. Light

Abstract

Forests of the Apalachicola River floodplain had shorter flood durations, were drier in composition, and had 17 percent fewer trees in 2004 than in 1976. The change to drier forest composition is expected to continue for at least 80 more years. Floodplain drying was caused by large declines in river levels resulting from erosion of the river channel after 1954 and from decreased flows in spring and summer months since the 1970s. Water-level declines have been greatest at low and medium flows, which are the most common flows (occurring about 80 percent of the time). Water levels have remained relatively unchanged during large floods which continue to occur about three times per decade.

A study conducted by the U.S. Geological Survey compared temporal changes in hydrologic conditions, forest composition, forest characteristics, and individual species of trees, as well as estimated the potential for change in composition of floodplain forests in the nontidal reach of the Apalachicola River. The study was conducted with the cooperation of the Florida Department of Environmental Protection and the Northwest Florida Water Management District. Forest composition and field observations from studies conducted in 1976-1984 (termed "1976 data") were used as baseline data for comparison with data from plots sampled in 2004-06 ("2004 data").

Flood durations were shorter in all periods subsequent to 1923-1976. The periods of record used to calculate flood durations for forest data were subsets of the complete record available (1923-2004). At sampled plots in all forest types and reaches combined, flood durations changed an average of more than 70 percent toward the baseline flood duration of the next drier forest type. For all forest types, changes in flood durations toward the next drier type were greatest in the upper reach (95.9 percent) and least in the lower reach (42.0 percent).

All forests are expected to be 38.2 percent drier in species composition by 2085, the year when the median age of surviving 2004 subcanopy trees will reach the median age (99 years) of the 2004 large canopy trees. The change will be greatest for forests in the upper reach (45.0 percent). Forest composition changes from pre-1954 to 2085 were calculated using Floodplain Indices from 1976 and 2004 tree-size classes and replicate plots.

Species composition in high bottomland hardwood forests is expected to continue to change, and some low bottomland hardwood forests are expected to become high bottomland hardwood forests. Organisms associated with floodplain forests will be affected by the changes in tree species, which will alter the timing of leaf-out, fruiting, and leaf-drop, the types of fruit and debris produced, and soil chemistry. Swamps will contain more bottomland hardwood species, but will also have an overall loss of tree density.

The density of trees in swamps significantly decreased by 37 percent from 1976 to 2004. Of the estimated 4.3 million (17 percent) fewer trees that existed in the nontidal floodplain in 2004 than in 1976, 3.3 million trees belonged to four swamp species: popash, Ogeechee tupelo, water tupelo, and bald cypress. Water tupelo, the most important tree in the nontidal floodplain in terms of basal area and density, has declined in number of trees by nearly 20 percent since 1976. Ogeechee tupelo, the species valuable to the tupelo honey industry, has declined in number of trees by at least 44 percent.

Greater hydrologic variability in recent years may be the reason swamps have had a large decrease in tree density. Drier conditions are detrimental for the growth of swamp species, and periodic large floods kill invading bottomland hardwood trees. The loss of canopy density in swamps may result in the swamp floor being exposed to more light with an increase in the amount of ground cover present, which in turn, would reduce tree replacement. The microclimate of the swamp floor would become warmer due to the decrease in shade and inundation. Soils would become dehydrated more quickly in dry periods and debris would decompose more quickly. A loss of tree density in swamps would lead to a decrease in tree and leaf litter biomass, which would have additional effects on swamp organisms. The loss of litter would result in a loss of substrate for benthic organisms in the floodplain and, ultimately, in the downstream waters of the river and estuary.

Introduction

The Apalachicola River is a large alluvial coastal plain stream with an extensive forested floodplain. Many species of plants and animals, both aquatic and terrestrial, live in the diverse aquatic and wetland habitats found in river floodplains. During floods, floodwaters are contained within floodplains and, when waters subside, floodplain soils retain moisture, ameliorating the effects of both floods and droughts, and improving water quality by removing contaminants. The benefits of protecting and maintaining healthy floodplain ecosystems have been described by many authors (Brinson and others, 1981; Clark and Benforado, 1981; Wharton and others, 1982; Davis and others, 1996; Messina and Conner, 1998; Mitsch and Gosselink, 2000).

Hydrology is the most important factor determining ecological processes in floodplains (Greeson and others, 1979; Gosselink and others, 1990; Lugo and others, 1990; Carter, 1996). Inundation, soil saturation, flood depths, and flowing water affect plant regeneration and survival and the consequent composition of floodplain forests (Light and others, 1993; 2002). Increased demands for water in the Apalachicola-Chattahoochee-Flint (ACF) River Basin (fig. 1) have resulted in conflicts among water-user groups in the States of Georgia, Alabama, and Florida, particularly during periods of regional drought. The effects of altered hydrologic conditions on floodplain forests, streams and sloughs, and the downstream river and estuary are important issues to be considered in resolving these conflicts.

The effects of drier hydrologic conditions on forest composition in river floodplains are usually not immediately evident, but gradual shifts in composition from flood-tolerant species to species of drier sites are expected to occur over time (Klimas, 1988). Results from a study by Palta and others (2003) indicate that decreased tree-diameter growth and possible changes in forest composition due to invading upland and exotic species were linked to changes in hydrology following dam construction on the Savannah River. Other effects of altered flow regimes on the Savannah River might be decreased seed transport and inhibition of seed germination and early growth in bald cypress and water tupelo seedlings. In these studies, floodplains have experienced either a decrease or an increase in flood durations. This report addresses the changes in Apalachicola River floodplain forests caused by drier conditions during low and medium flows without a significant change in conditions during large flood events.

Purpose and Scope

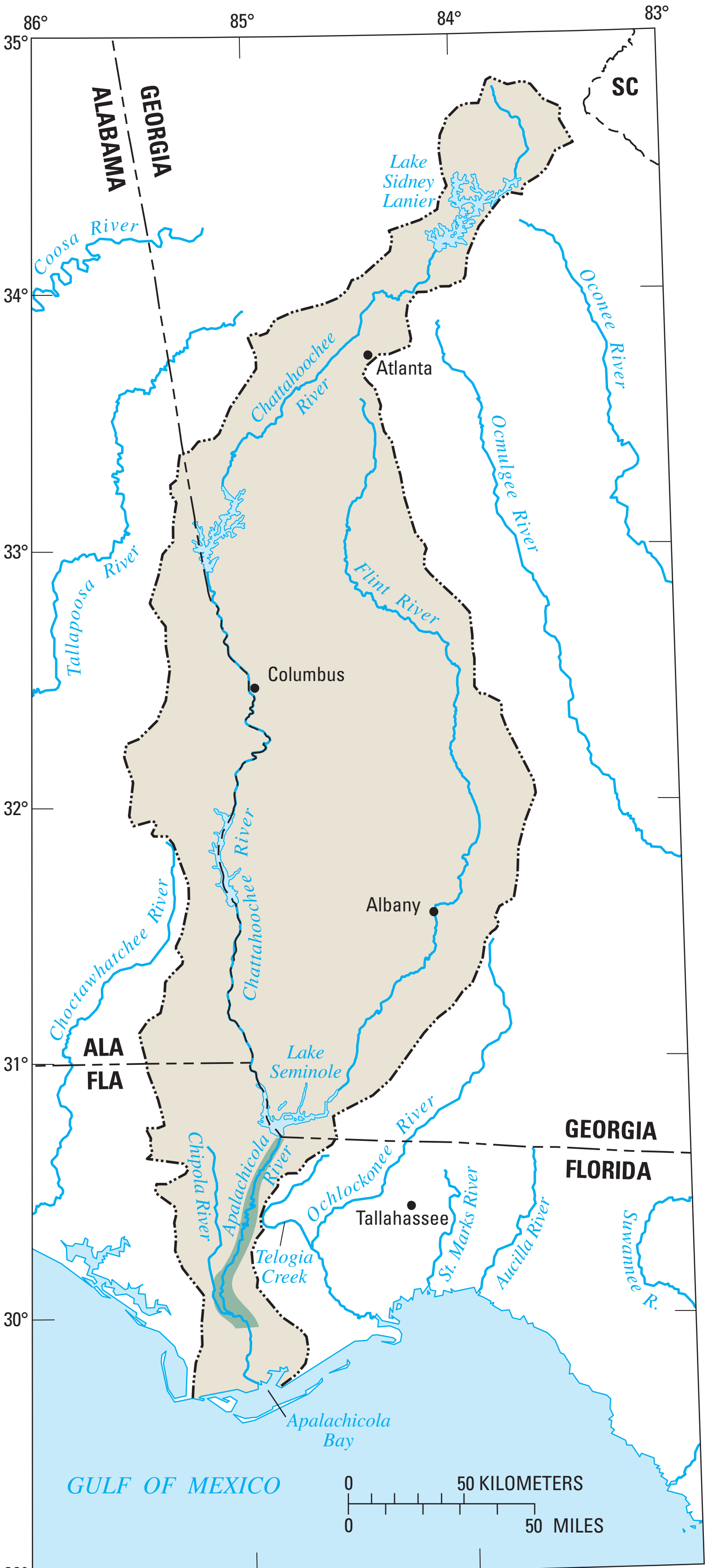
A study was conducted by the U.S. Geological Survey (USGS) with the cooperation of the Florida Department of Environmental Protection (FDEP) and the Northwest Florida Water Management District (NWFWMD) to assess changes that have occurred in forests in the nontidal floodplain of the Apalachicola River. The objectives of this report are to:

- Compare 1976 to 2004 hydrologic conditions in floodplain forests;
- Compare 1976 to 2004 composition of floodplain forests;
- Describe changes in other forest characteristics, including changes in abundance of individual species of trees; and
- Estimate the potential for future change in composition of floodplain forests.

The study area includes the nontidal reach of the Apalachicola River from the Jim Woodruff Dam at river mile (rm) 106.4, downstream to the beginning of the tidal reach at rm 20.6 (fig. 2). Fieldwork conducted to sample 2004 forest composition was performed from October 2004 to August 2006.

Acknowledgments

The authors are indebted to many people who contributed fieldwork and technical assistance. Among them are Lee Reed, Tony Stallins, Keith Smith, Angus Gholson, Grayal Farr, Matt Smith, Zachary Rapple, Kelly Watson, Leigh Brooks, and Vicki Dezsö, volunteers; Terry Petrosky, Alejandro Sepulveda, Lori Lewis, Marian Berndt, Gary Mahon, and Jack Grubbs of the USGS, and Graham Lewis of the NWFWMD. The authors also appreciate the technical review comments of Mary Davis of The Nature Conservancy and Robert Mattson of the St. Johns River Water Management District; and administrative guidance from Graham Lewis of the NWFWMD, Gary Mahon of the USGS, and John Outland of the FDEP. Assistance from the USGS publications staff was also appreciated, particularly Ron Spencer for graphics, and Twila Darden Wilson for editorial review and layout.



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

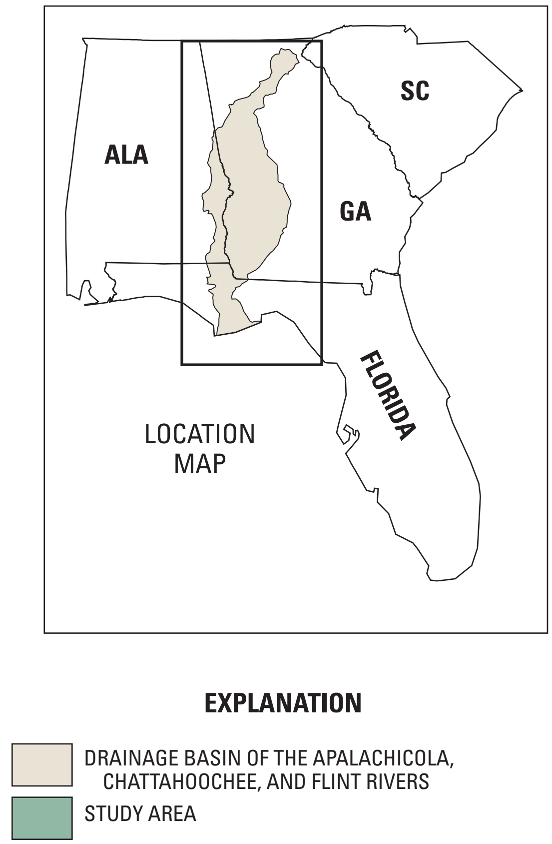


Figure 1. Drainage basin of the Apalachicola, Chattahoochee, and Flint Rivers in Florida, Georgia, and Alabama.

Setting and Background

The Apalachicola River is formed by the confluence of the Chattahoochee and Flint Rivers near the Georgia-Florida State line (fig. 1). The ACF basin covers an area of 50,800 square kilometers (km^2). The Chattahoochee and Flint Rivers in Georgia and Alabama drain about 90 percent of the basin. The remaining 10 percent of the basin, located primarily in Florida, is drained by the Apalachicola River and its largest tributary, the Chipola River. The Apalachicola River floodplain is the largest floodplain in Florida with 33,300 hectares (ha) of bottomland hardwood forests and swamps in the nontidal reaches. More than 70 tree species grow in the Apalachicola River floodplain, ranking this area as high among North American floodplains in tree species richness (Brinson, 1990).

Floodplain Study Area and Forest Types

The floodplain of the Apalachicola River is the land covered by water from the river during the typical annual flood (2-year, 1-day high flow). Flooding usually occurs in late winter through early spring with low flows in September through November (Leitman and others, 1984). The floodplain is within the physiographic area called the Coastal Lowlands (Puri and Vernon, 1964), an area that is generally low in elevation; the fall of the nontidal river from its head at Jim Woodruff Dam to rm 20.6 is about 12.5 meters (m) over a stream length of 137 km (Light and others, 2006), an average gradient of 0.09 meters per kilometer (m/km). Soils in the nontidal Apalachicola River floodplain are predominantly clay with some silt-clay and clay loams. Sandy soils are found on sandbars, high ridges, and levees.

The nontidal floodplain of the Apalachicola River is divided into three reaches (fig. 2). The upper reach begins just below Jim Woodruff Dam at rm 106.4 and extends about 47 km downstream to a streamflow gaging station (gage) located near Blountstown at rm 77.5. The middle reach is the longest reach, about 58 km long, ending at a gage near Wewahitchka at rm 41.8. The nontidal lower reach is about 34 km long, extending from Wewahitchka to a gage near Sumatra at rm 20.6. In the upper reach, the floodplain is 2-3 km wide with high bluffs on the eastern bank. The floodplain valley widens in the middle and lower reaches to a maximum width of 6-8 km. The tidal reach was not included as part of this study.

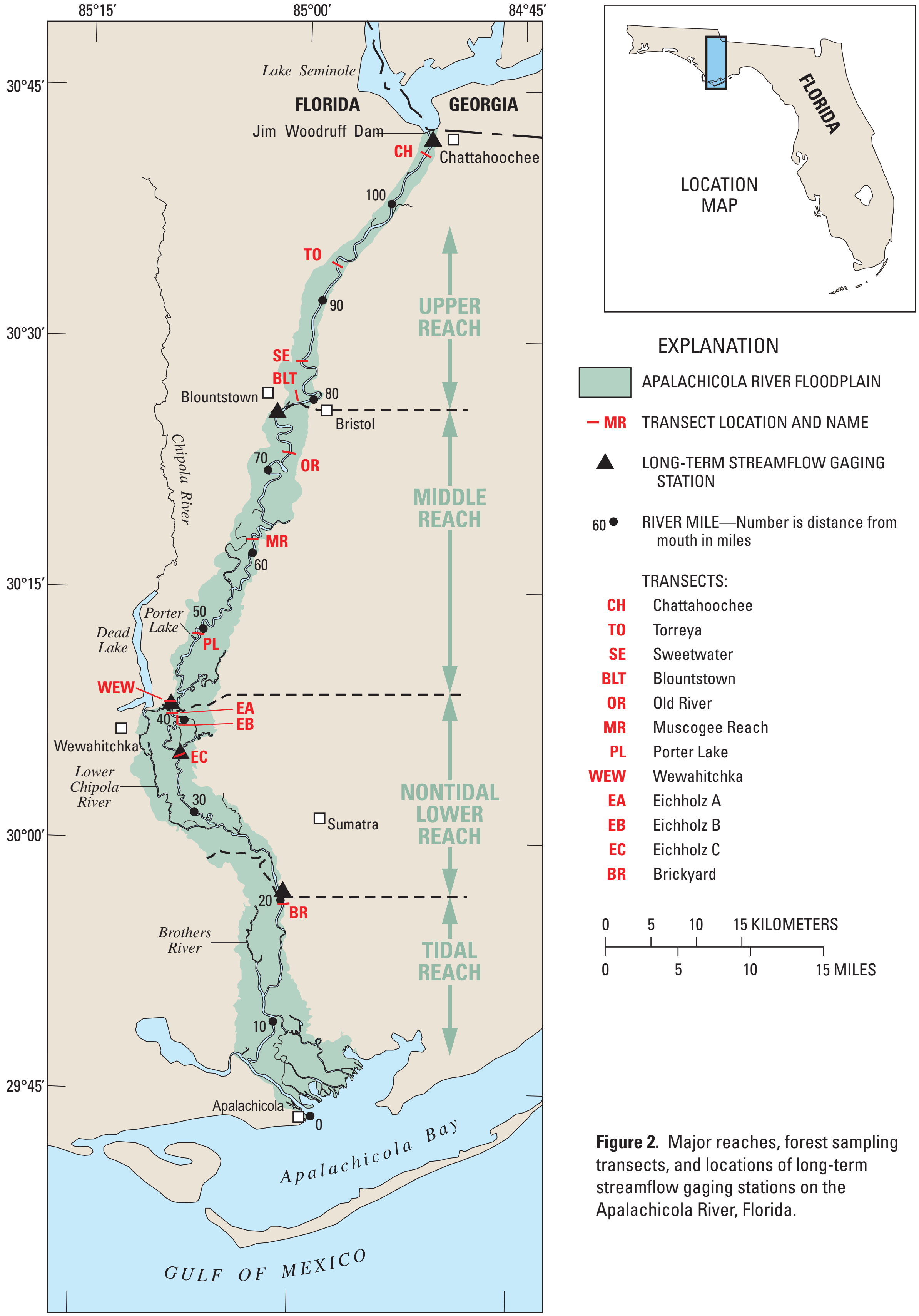
The lowest elevations of the floodplain (excluding permanent open-water bodies) are tupelo-cypress swamps that are continuously flooded for 4 to 9 months each year. Low bottomland hardwood (Loblh) forests are present on low ridges and flats where continuous flooding lasts 2 to 4 months yearly. High bottomland hardwood (Hiblh) forests grow on the higher elevations of the floodplain (levees and ridges) that are commonly inundated for 2 to 6 weeks each year (Leitman and others, 1984).

Population and development along the river are relatively sparse. Timber interests control large parts of the upper and middle reaches of the floodplain, but the lower reach is now principally conservation lands owned by the State of Florida. Cypress trees were systematically logged throughout the floodplain from the 1880s to the 1920s, and only a small number of very large, old cypresses remain today. Most of the logging of the past was selective cutting for desirable timber trees (Neal Land and Timber Company, oral commun., 2004), but more recently, many areas of the floodplain have been clear-cut or nearly so. Aerial photographs of the floodplain taken in 1941 show a mostly continuous forest canopy with faint striations that were probably caused by draglines from the removal of cypress trees (fig. 3).

Water-Level Decline in the Apalachicola River

Water levels have declined over the past 50 years as a result of both erosion of the river channel locally and decreased spring and summer flows from the upstream watershed (Light and others, 2006). The combined effects of both types of water-level declines vary by location along the river and have been greatest at low and medium flows of less than 850 cubic meters per second (m^3/s) (30,000 cubic feet per second (ft^3/s)), which are the most common flows (occurring about 80 percent of the time). Declines have been most severe during drought conditions in the spring and summer months of April, May, July, and August, with river levels 1.9 m lower at the Chattahoochee gage and 0.9 m lower for most of the remaining nontidal river (fig. 4). Water levels have not declined appreciably during large floods of 2,830 m^3/s (100,000 ft^3/s) or greater, which continue to occur as frequently as prior to 1954 (about three times per decade).

In the upper 64 km of the Apalachicola River, water-level declines caused by channel erosion occurred primarily as a consequence of the construction of Jim Woodruff Dam in 1954. Trapping of sediment in the reservoir formed by the dam resulted in the scour of riverbed sediments downstream from the dam. The influence of the dam on bed scour was greatest just downstream from the dam, where a decline of 1.5 m occurred, and progressively decreased with increasing distance from the dam to a decline of 0.3 m about 16 km downstream from Blountstown. The relatively large water-level decline of 0.9 m near rm 35 in the lower reach of the river (fig. 4) was probably a result of several meander cut-offs (rerouting of the river channel at bends in the river) constructed in 1956 and 1969 that shortened the length of the river in the lower reach by 3.2 km. (When river straightening shortens a river, it steepens the slope of the riverbed, increasing flow velocity and, therefore, increasing bed scour.) In addition, dredging, dredged material disposal, snagging (dead tree removal), and other navigational improvements conducted throughout the entire nontidal river probably contributed to water-level declines in all reaches. Channel maintenance practices were changed in the late 1970s to reduce environmental impacts.



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 2. Major reaches, forest sampling transects, and locations of long-term streamflow gaging stations on the Apalachicola River, Florida.

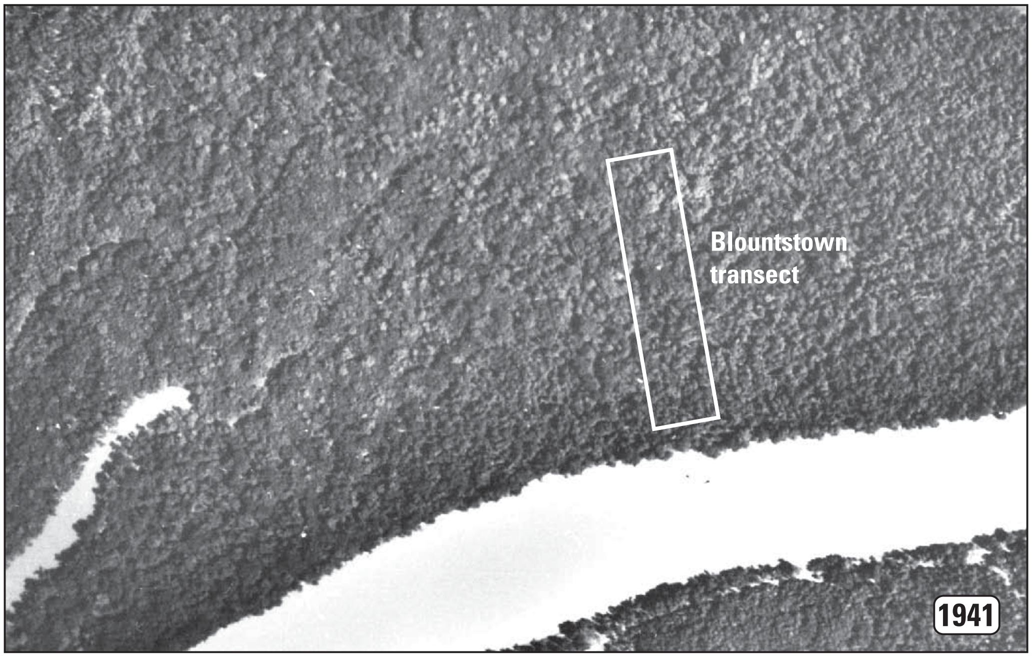


Figure 3. The forest canopy in 1941 in the vicinity of the BLT transect on the Apalachicola River floodplain, Florida. The tree canopy appears relatively mature and nearly continuous despite the removal of cypress trees that primarily took place from the late 1880s to the early 1920s.

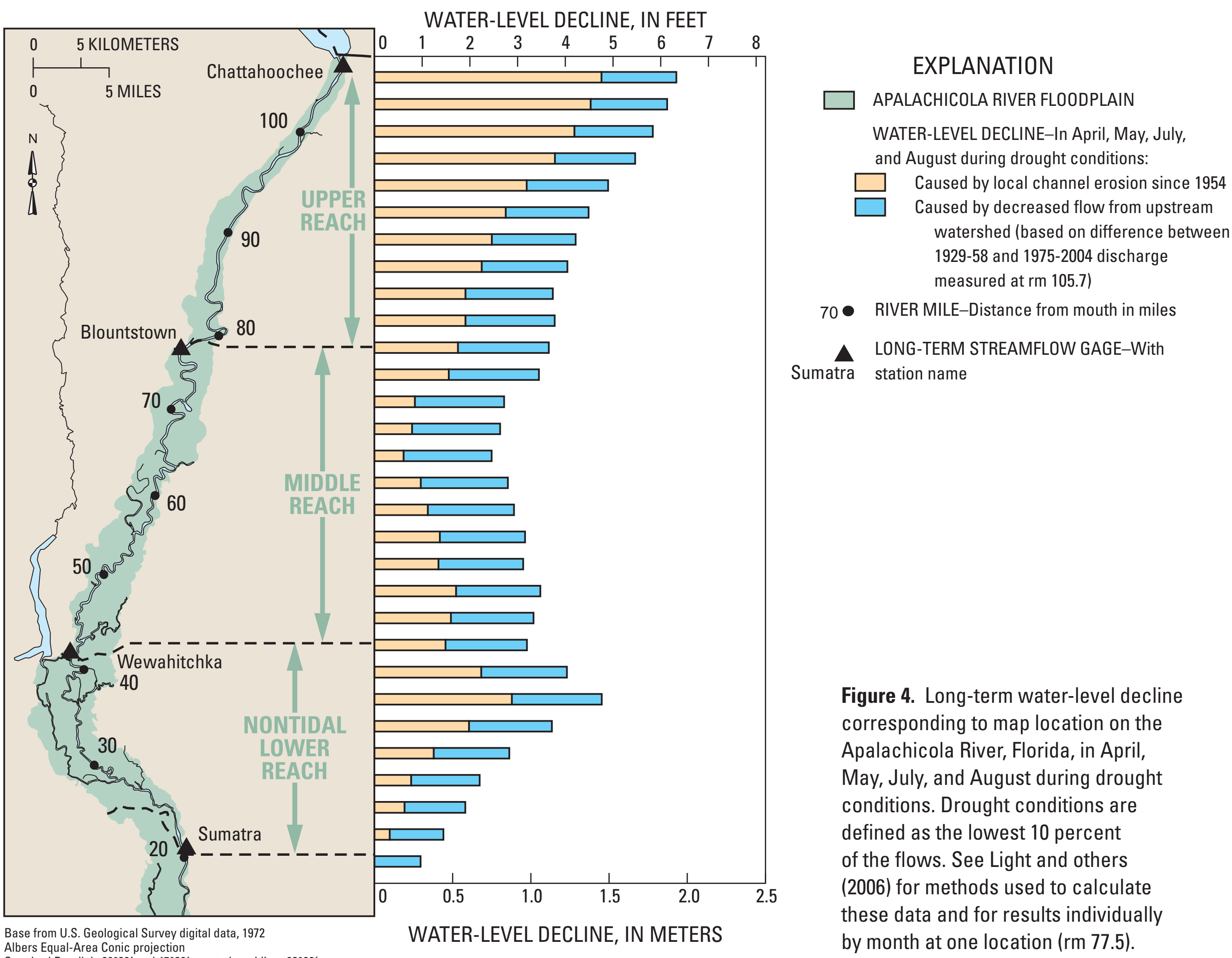


Figure 4. Long-term water-level decline corresponding to map location on the Apalachicola River, Florida, in April, May, July, and August during drought conditions. Drought conditions are defined as the lowest 10 percent of the flows. See Light and others (2006) for methods used to calculate these data and for results individually by month at one location (rm 77.5).

As a result, additional water-level declines from channel erosion since the late 1970s have been relatively minor (Light and others, 2006).

Decreased spring and summer flows from the upstream watershed during drought conditions have resulted in further declines since 1975 that have lowered water levels throughout the entire river. Water-level declines caused by these seasonal decreases in flow have been similar to or greater than the declines caused by channel erosion along 90 km of the river and for more than two-thirds of the nontidal floodplain, primarily in the middle and lower reaches (fig. 4). Less flow during the spring and summer in recent decades is likely caused by a combination of changes in rainfall patterns and increased human activities in the ACF basin, including agricultural irrigation, municipal water use, flow regulation, and reservoir evaporation (Light and others, 2006).

Influence of Flooding on Tree Seedling Regeneration in Floodplain Forests

Overbank flooding subjects floodplain forests to inundation, saturation, or flowing water conditions. Seeds of trees in the floodplain usually do not germinate underwater, so seedlings become established between floods. The long duration of inundation and deep flooding that occur in floodplain swamps control forest composition primarily through a process of exclusion, drowning the seedlings of most bottomland hardwood species before they can become established (Hosner, 1960; Light and others, 1993). The seedlings of two common swamp trees, water tupelo and bald cypress, are more likely to survive in swamps because they grow faster than most bottomland hardwood species (Harms, 1973; Brown, 1984). Taller seedlings are less likely to be totally submerged by floods. Swamp tree species also have various physiological adaptations for growing in saturated, anoxic soils (Harms, 1973; Hook and Crawford, 1978; Brown, 1984). Solitary individuals of bald cypress grow well at higher elevations in the floodplain, and even do well when planted on upland sites, but natural stands with large numbers of bald cypress trees are present only where flooding lasts long enough to limit competition from other species. Limited competition is also a necessary prerequisite for the establishment of water tupelo trees, but unlike bald cypress, water tupelo requires wet conditions to thrive in the seedling stage and will not grow well under drier conditions (Applequist, 1959a, 1959b; Dickson and others, 1965). More tree species are adapted for survival in bottomland hardwoods where flood durations are shorter than in swamps. Bottomland hardwood species that recover quickly from periods of inundation and saturation in the growing season have a competitive advantage in river floodplains over upland species.

Methods

Basal area, density, and other characteristics of forest composition were sampled using different methods in several studies conducted from 1976 to 1984 and in the present study from 2004 to 2006. River stage records at each forest transect were estimated from long-term streamgage records and used to calculate flood duration, depth, and frequency by forest type and reach.

Forest Sampling

Four previous forest sampling studies conducted from 1976 to 1984 provided baseline information for the current study:

- The Leitman thesis study (Leitman, 1978) (hereafter called the "thesis study");
- The Apalachicola River Quality Assessment (ARQA) study (Leitman and others, 1984);
- The Eichholz study (Eichholz and others, 1979); and
- The Gholson study (Gholson, 1985).

Forest sampling was repeated during the current study in 2004-06 at many of the sites sampled previously from 1976 to 1984.

Quantitative results from the thesis study (conducted 1976-77) and the ARQA study (conducted in 1979) are collectively referred to as "1976 data," and recent sampling (conducted 2004-06) is referred to as "2004 data." The 2004 data were collected at 12 transects in the nontidal river floodplain (fig. 2). The following abbreviations are used throughout this report for identifying the transects: CH, Chattahoochee; TO, Torreya; SE, Sweetwater; BLT, Blountstown; OR, Old River; MR, Muscogee Reach; PL, Porter Lake; WEW, Wewahitchka; EA, EB, and EC, Eichholz transects A, B, and C; and BR, Brickyard.

A comparison of methods used to collect and analyze 1976 and 2004 data is presented in table 1. All individual sample points and plots in this study are called "plots" regardless of sampling methods used to obtain data.

Thesis Study, 1976-77

The objective of the thesis study was to correlate elevations, water levels, and soils to tree communities on the Apalachicola River floodplain. Two transects, BLT and WEW, were located near gaging stations on the river and were each about 1 ha in size (Leitman, 1978). All trees greater than or equal to (≥) 7.5 centimeter (cm) in diameter at breast height (dbh) were identified, measured for dbh, surveyed for elevation, and mapped using an alidade and plane table. Buttressed, forked, or deformed trees were measured for dbh according to methods in Avery (1967).

Table 1. Methods used to collect and analyze 1976 and 2004 composition data from forests of the Apalachicola River floodplain, Florida.

[ARQA, Apalachicola River Quality Assessment; cm, centimeter; dbh, diameter at breast height; GIS, geographic information system; GPS; global positioning system; ha, hectare; m, meter; m^2, square meters; rm, river mile]

Task or parameter sampled	Sampling and analysis methods			
	1976 data			2004 data
	Thesis transects [a]	ARQA data [b]		
		Cruise transects	Intensive plots	
Location and selection of sampling transects, points, and plots	Transects (BLT and WEW) placed near gages. Sites selected for relatively undisturbed, mature forest appearance and presence of all forest types. Sites subdivided into 11 plots (5 at BLT, 6 at WEW [c]) based on ground elevations and species associations.	Transects spaced at regular intervals along the downstream gradient. Transect at rm 29 and parts of two other transects not sampled due to logging or agricultural use. Points spaced at regular intervals (usually 91.5 m apart) along transects.	Plots located on two ARQA cruise transects (SE and BR). Plots selected for relatively undisturbed, mature forest appearance.	Approximate location of most plots determined on GIS and then located in field using GPS. Exact location of BLT and WEW plots established in field. Plots typically placed in relatively undisturbed, mature forests.
Tree sampling method	All trees within a defined area identified and measured. Trees mapped using alidade and plane table.	Cruise sampling using glass wedge prisms to select trees to be identified and measured.	All trees in a plot with an area of 506 m^2 identified and measured.	All trees in plot with an area of 531 m^2 identified and measured. Surviving original trees at BLT and WEW transects identified, tagged, and measured; new trees identified and measured.
Sizes of trees sampled	All trees with dbh ≥ 7.5 cm	No size limits. Original data included 42 trees with dbh ≥ 2 and < 7.5 cm that were not used in analysis.	All trees with dbh ≥ 7.5 cm	All trees with dbh ≥ 2.5 cm. For trees with dbh ≥ 2.5 and < 7.5 cm, dbh recorded as "less than" (exact dbh not recorded).
Dates of data collection	September 1976 to September 1977	August 1979 to December 1979	August 1979 to December 1979	October 2004 to August 2006
Calculation of basal area	basal area = πr^2	The basal area of every tree sampled at each cruise transect point was equal to the basal area factor of the prism used at that point.[d]	basal area = πr^2	basal area = πr^2
Calculation of density	density = number of trees/ha	$3183.0989/(\text{dbh X PRF})^2$, where PRF = "plot radius factor" for prism used.[d]	density = number of trees/ha	density = number of trees/ha

[a] Leitman (1978).
[b] Leitman and others (1984).
[c] One plot on a point bar with a young pioneer forest was not included in this study.
[d] Calculations of basal area and density based on Avery (1967).

Trees with multiple trunks were counted as one tree, and only the largest trunk was measured for dbh. The cross-sectional area of each tree trunk was computed from the dbh (area = πr^2) and summarized as basal area in square meters per hectare. Density was determined as the number of trees per hectare. Transects were subdivided into 11 plots (5 at BLT, 6 at WEW) based on ground elevations and species associations. Species dominance at plots was calculated as relative basal area (rba; the sum of basal area for all trees of each species divided by the total basal area at each plot) and as relative density (rd; the total number of trees of each species divided by the total number of trees on each plot). Data collection took place from September 1976 to September 1977.

Apalachicola River Quality Assessment (ARQA) Study, 1979

The ARQA was part of a national USGS river water-quality assessment program. One of the objectives of the ARQA was to relate the distribution and composition of floodplain forests to hydrologic conditions. Vegetation data for ARQA studies was collected at two types of sites, cruise transects and intensive plots, employing two different sampling methods. Forests on cruise transects were sampled with methods that were developed to enable timber cruisers to rapidly assess the overall condition of large forest stands by sampling at many points with a minimum amount of data collected at each point (Kulow, 1965; Avery, 1967). Forests at intensive plots were sampled using standard plot-sampling methods to quantify forest composition in more detail (Leitman and others, 1984). Vegetative data collection at ARQA cruise transects and intensive plots began in August 1979 and continued through December 1979.

Cruise Transects

Seven cruise transects (CH, TO, SE, OR, MR, PL, and BR) across the floodplain were approximately equally spaced from the Jim Woodruff Dam at Chattahoochee to just downstream from the gage at Sumatra (fig. 2). One of these transects, PL, did not span the full width of the floodplain because of logging activities. No transect was surveyed between the Wewahitchka gage and the Sumatra gage because of clear-cutting at the selected location. Although the BR transect is 0.8 rm downstream from the Sumatra gage, data from the eastern half of the transect were included in the current study, because tidal influence is minimal in forests on the eastern end of the transect. An eighth cruise transect located downstream from BR was not used in the current study, because the transect was tidally influenced. Locations of transects in the field were determined using USGS quadrangle maps and field-reckoning techniques. Cruise-transect sampling points were usually spaced at 91.5 m intervals across each transect, determined by pacing along a predetermined bearing using a handheld compass.

Sampling at each point along cruise transects was conducted using glass wedge prisms. The prism-sampling method uses no minimum tree diameter limit and no defined plot size. Species, dbh, and prism basal area factor were recorded for every tree sampled at each point. The prism basal area factor was selected in the field based on the heterogeneity of the plot and the optimum number of trees per sample. Basal area and density were calculated for tree species at sampled points using the formulas listed in table 1 which were developed for timber cruising using the prism-sampling method (Kulow, 1965; Avery, 1967). Although data from cruise transects were obtained at sampling points, all locations where data were collected are referred to as "plots" for convenience when discussing data from multiple studies. ARQA cruise-transect data were the only data used in this report that were collected by using the prism-sampling method.

Five forest types designated A through E were defined using the conventions of Eyre (1980). Types A and B were bottomland hardwood forests and C, D, and E were swamp types. Out of 160 cruise-transect plots surveyed in the nontidal reaches, 13 plots were not assigned forest types because forest definitions did not cover all possible compositions and were not mutually exclusive.

Intensive Plots

At 16 intensive plots on two of the cruise transects (SE and BR) hydrologic and vegetative data were collected more intensively than at cruise-transect plots. Five of the intensive plots on the western end of the BR transect were not used in the current study because of tidal influence. Intensive plots were located on or close to the cruise transects in all forest types. The optimum plot size was determined by conducting a nested-plot test (Mueller-Dombois and Ellenberg, 1974). Intensive plots were square and 506 square meters (m^2) in area. Rules for determining dbh and basal area were similar to those used on the thesis plots (Leitman, 1978). Species and diameter were determined for every tree in the plot with a dbh $\geq$ 7.5 cm. Calculations of basal area, rba, density, and rd were made for species in each plot. Forest-type designations were the same as those developed for cruise transects.

Eichholz Study, 1978

The purpose of the Eichholz study was to assess the impact of U.S. Army Corps of Engineers (USACE) dredged material disposal practices on fish and wildlife resources of the Apalachicola River (Eichholz and others, 1979). Twelve spoil disposal sites were selected for sampling; five of these sites were located in the nontidal part of the floodplain. At each site, transects perpendicular to the river's edge were established across spoil sites and in adjacent areas not affected by disposal. The unaffected transects were controls for assessing the effects of disposal practices. Site maps were created and points at 30-m intervals along transects were sampled using a point-centered quarter method. Ash (*Fraxinus*) and gum (*Nyssa*) trees were not identified to species. Data were collected in November 1978. Average percentage cover for species for entire transects was summarized in tables, but forest composition at the original sampling points is unknown because the raw field data from this study are not available. Although quantitative forest composition data from the Eichholz study were not used in the current study, 1978 site maps and summarized forest data were helpful in classifying 22 new plots that were located on three Eichholz control-site transects (EA, EB, and EC) and sampled in the 2004 data. In addition, lists of species from the Eichholz study were compared with 2004 data for analysis of the distribution of species.

Gholson Study, 1984

The purpose of the Gholson study was to collect vegetation data on and near within-banks disposal sites and compare it to vegetation on undisturbed sites to assess biological impacts of within-banks disposal (Gholson, 1985). A total of 17 study sites were located along the main channel, 11 of which were located in the study area of the current study (5 at disposal sites, 6 at nondisposal sites). During the months of October and November 1984, a large area was surveyed at each site for plant species in several topographic zones defined by Gholson. Results in the Gholson report include lists of plant species from all strata, maps, photographs, and a brief description of the condition and aspect of each site. Lists of species from the Gholson study were compared with 2004 data for analysis of the distribution of species.

Current Study, 2004-06

Forest composition was sampled at 95 plots located along 12 transects (2 thesis transects, 7 ARQA cruise transects, and 3 Eichholz transects). At the thesis transects (BLT and WEW), the exact location of the plots was recovered and surviving individual trees were remapped. Part of the original levee plot at BLT had eroded into the river, and the WEW transect was logged sometime between 1999 and 2004, completely destroying two of the original six plots (fig. 5). Two plots (one was an old sandbar that was not used in the current study) remained intact, and two plots were partially intact. Comparisons between 1976 and 2004 forest composition for damaged plots were based on partial plots with boundaries defined by the 2004 extent.

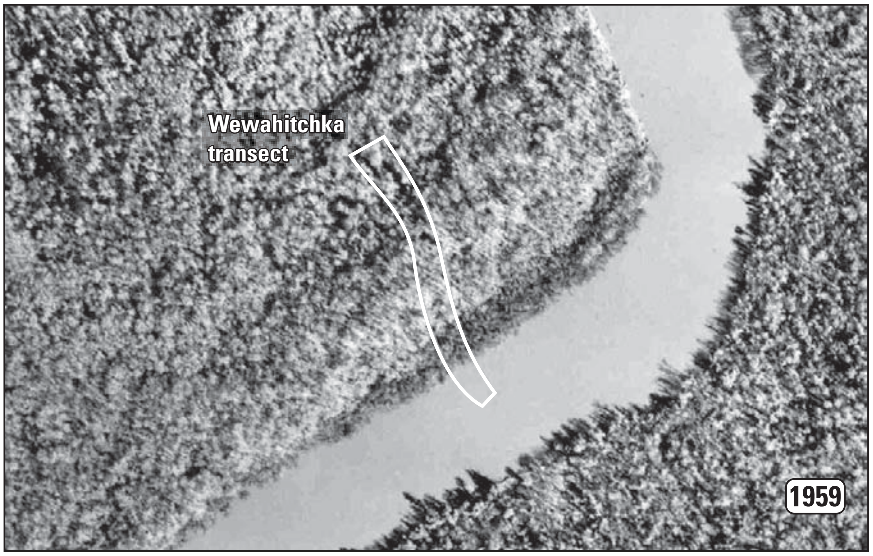
The exact locations of original ARQA cruise transects, ARQA intensive plots, and Eichholz transects were not recoverable, so transects were drawn on Geographic Information System (GIS) maps using maps, aerial photographs, and field notes from the original studies. The coordinates of plots to be sampled were determined in the office on GIS maps to reduce the possibility of being subjectively located in the field. Plots in the most undisturbed areas of forests were selected for sampling in the field from the set of predetermined locations after traversing the entire transect. Three plots (two at OR and one at MR) were located between cruise-transect plots in homogeneous sections of the OR and MR transects because the predetermined plot locations were in transitional areas. Two plots were located in undisturbed areas near the CH and WEW transects, because the predetermined plots had been clear-cut. Two of these plots at WEW were replicates for clearcut thesis plots. Twenty-two plots at the Eichholz transects were spaced 50 m apart to prevent unintentional overlap resulting from global positioning system (GPS) error. Although the original Eichholz data collected in 1978 could not be used in this study, new plots along the Eichholz transects (EA, EB, and EC) were added to the 2004 data to provide information on forest composition and hydrologic conditions in a part of the lower reach that was not otherwise sampled.

Replicate plots sampled in 2004 were placed at the exact location as thesis plots or as close as possible to the location of plots sampled in 1976. There were 71 pairs of replicate plots, each of which had a 1976 sample and a 2004 sample for a total of 142 plots. The replicate plot group does not include 110 plots sampled in 1976 that were not replicated in 2004, and 24 plots sampled in 2004 that had no 1976 replicates (1 near CH transect, 1 near WEW transect, and 22 at EA, EB, and EC).

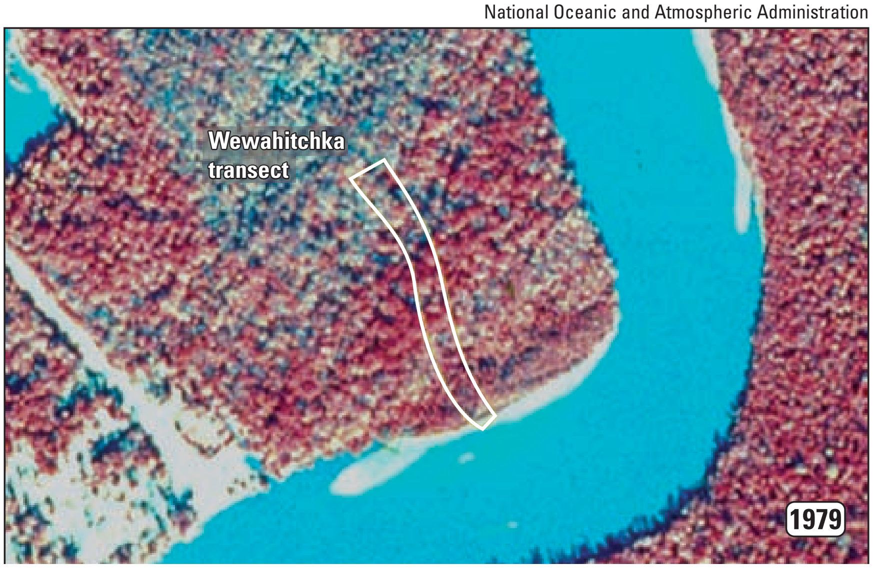
Plots in the 2004 dataset (with the exception of extant thesis plots) were circular with a 13 m radius and an area of 531 m^2, and were created using fiberglass tape and flagging to delineate the outer perimeter. All trees with a dbh $\geq$ 7.5 cm (termed “canopy trees” in this report) were identified to species and measured for dbh. Common names of tree species are used throughout this report. A list of common and scientific names is given in appendix 1. Rules for determining dbh and basal area were the same as those used on the thesis and ARQA intensive plots. In addition to canopy data, trees with a dbh less than (<) 7.5 cm but $\geq$ 2.5 cm and greater than (>) 3 m in height (termed “subcanopy trees”) were identified to species and counted. Exact dbh measurements were not recorded for subcanopy trees. Subcanopy dominance was based on density, because it is an appropriate measure of dominance of trees with small dbhs. Calculations of basal area, rba, density, and rd (density and rd only for subcanopy trees) were made for individual species at each plot.

A visual estimate of the extent of ground cover was made and the dominant ground-cover species recorded. If surface water was present, a percent estimate of the extent of the plot covered by water and the depth of water was noted. A numbered aluminum tag was nailed into the tree closest to the center of each plot. Plots may be recoverable for future surveys depending on the accuracy of GPS locations, logging activities, and the survival of marked trees.

Florida Department of Transportation



National Oceanic and Atmospheric Administration



Florida Department of Environmental Protection

Figure 5. Changes at the WEW transect on the Apalachicola River floodplain, Florida, from 1959 to 2004. When the transect was originally established in 1976, there was a young pioneer forest at the south end that is visible in the 1979 photograph but was unvegetated and underwater in the 1959 photograph. The 2004 photograph shows continued accretion on this point bar extending well beyond the south end of the transect. The red arrow on the 2004 photograph indicates a small remnant of swamp that was left after most of the transect was clear cut.

Analysis of Forest Data

Rules for determining forest types for 1976 plots were developed using dominance of species**.** Basal area and density from all plots were weighted by area of forest types to determine the composition of 1976 and 2004 forest types and the abundance of species throughout the nontidal floodplain. Replicate plot data were used to calculate average basal area and density for forest types and species groups. Growth rates, tree ages, mortality, and recruitment of tree species were calculated from the data on individual trees available from the thesis plots. A Floodplain Index (FI) was developed to quantify and compare composition of forests on a scale of relative wetness or dryness from swamp to upland forests.

Forest Type Determinations using Floodplain Species Categories

Forest types for all plots in the 1976 data were redetermined using the dominance of species weighted by a factor developed in this study called the Floodplain Species Category (FSC). The assignment of FSCs to tree species was based principally on the typical habitat where tree species grew on the Apalachicola River floodplain during 1976-79. Species were grouped into four categories, FSC1, FSC2, FSC3, and FSC4, with corresponding values from 1 to 4. FSC1 species were more dominant in swamps; FSC2 species were more dominant in Loblh; FSC3 species were more dominant in Hiblh; and FSC4 species were atypical bottomland hardwood species or upland species that were found on the higher elevations of the floodplain. Additional sources of information used to determine FSCs for species were dominance patterns on five other north Florida stream floodplains (Light and others, 1993, 2002), wetland indicator status (Reed, 1988), and other accounts of tree species (Fowells, 1965; Clark and Benforado, 1981). The FSC assigned to each species in the 1976 and 2004 data is listed in appendix 1.

All plots from the 1976 data were redetermined as three forest types: Hiblh, Loblh, and swamps by applying rules based on the dominance of species weighted by FSC categories (table 2). Rules were designed to be mutually exclusive and to yield a type determination for all possible forest compositions. Canopy dominance was calculated from basal area in this study, because basal area more closely represents cover or biomass for canopy trees than density. Previous studies in the Apalachicola River and on other north Florida streams used basal area as the principal determinate of forest type. An example of the calculation of forest type for a hypothetical forest plot is shown in table 2.

Redeterminations using the above rules resulted in forest types that were like those used in the ARQA study (Leitman and others, 1984), with Hiblh similar to their "Type A" forest, Loblh forest similar to "Type B", and swamps analogous to forest types C, D, and E. Other forest types used in the ARQA study ("Pioneer" and "A/pine") were not included in the present study. Previous rules for determining forest types used by Leitman and others (1984, p. A31) were not mutually exclusive, and 8 percent of the cruise-transect plots remained unclassified in that study, because they did not fit any of the forest types. Using the new rules, 4 cruise-transect plots (out of a total of 160) and 1 ARQA intensive plot changed forest type from that which was originally assigned, and all 13 previously unidentified cruise-transect plots were given a forest type.

To measure change from baseline (1976) to recent (2004) conditions, plots sampled in 2004 needed to be assigned the same forest type as the original plot in 1976, regardless of their 2004 composition. Therefore, all forest type determinations for the 2004 data were based on the forest types determined for 1976 plots from the rules created in this study. At the 24 plots that did not have a replicate in 1976 (1 at CH; 1 at WEW; and 22 at EA, EB, and EC), the 1976 forest types were estimated by locating the plots on 1979 aerial infrared photographs and designating a 1976 forest type based on visual signatures, site maps (Eichholz and others, 1979), and a floodplain forest map (Leitman, 1984). Throughout this report all 1976 and 2004 data are grouped by the redetermined 1976 forest types.

Basal Area and Density

Basal area and density of species from all plots (181 plots sampled in 1976 and 95 plots sampled in 2004) were weighted to determine the composition of each forest type throughout the entire nontidal floodplain and to provide information on changes from 1976 to 2004 in the total basal area and number of trees in the floodplain. The same analysis of basal area and density of species was repeated using unweighted data from the replicate plots (71 pairs, 142 plots). Changes in basal area and density from 1976 to 2004 for all plots and for replicate plots were statistically analyzed using t-tests (paired two-sample test for means).

Species Composition of Forest Types

Forest type composition was calculated separately for the two 1976 sampling-methods sets: (1) ARQA cruise-transect data, sampled with prisms without defined plot sizes and (2) thesis and ARQA intensive-plot data combined, sampled with defined plot sizes. The separation of the 1976 data into the two sets was done to allow a comparison of composition determined by the two different sampling methods. Basal area and density for each species were determined for each plot individually. Data from each plot were considered equal, regardless of plot size. Data from all plots in each forest type in each reach were summed and then divided by the number of plots to yield the average basal area and density values of each forest type in each reach.

Average basal area and density of species in each forest type for each reach were weighted by a factor based on the area of each forest type in each reach of the floodplain. Weighting was necessary for several reasons: (1) forest types

Table 2. Use of Floodplain Species Categories to calculate forest types for plots sampled in the Apalachicola River floodplain, Florida.

[The Floodplain Species Category (FSC) is based on the typical forest association for the species in 1976 data. Hiblh, high bottomland hardwood; Loblh, low bottomland hardwood; rba, relative basal area; >, greater than; ≥, greater than or equal to; <, less than; %, percent]

FSC value	Occurrence and dominance in 1976 Apalachicola River floodplain forests
1	More dominant in swamps
2	More dominant in Loblh
3	More dominant in Hiblh
4	Atypical bottomland hardwood or upland species

Example of forest type calculation for a hypothetical forest plot:

Species[a]	Rba, in percent	FSC value	Rba of FSC2 species, in percent	Rba of FSC3 species, in percent	Rba of FSC4 species, in percent
water hickory	26.6	2	26.6		
American elm	2.6	2	2.6		
hackberry	23.0	3		23.0	
sweetgum	19.9	3		19.9	
box elder	14.9	3		14.9	
water oak	2.4	3		2.4	
persimmon	1.8	3		1.8	
possum haw	0.5	3		0.5	
winged elm	8.3	4			8.3
Total	100.0		29.2	62.5	8.3

Rules for defining forest types:

Swamp	Total rba of FSC1 species ≥ 50%
Loblh	Total rba of FSC1 + FSC2 species ≥ 50% and total rba of FSC1 is < 50%
Hiblh	Total rba of FSC3 + FSC4 species ≥ 50% and total rba of FSC4 is < 50%
Upland	Total rba of FSC4 species ≥ 50%

Application of rule to determine forest type in above example:

Total rba of FSC3 + FSC4 species ≥ 50% and total rba of FSC4 species is < 50%, so forest type is Hiblh.

[a] See appendix 1 for scientific names.

change in species composition from the upper to the lower reach, (2) forest types vary in area from reach to reach, and (3) sampling was not done in either 1976 or 2004 in proportion to the amount of each forest type in each reach. The areas of forest types in each reach were derived from a digitized and edited GIS version of a floodplain map created by Leitman (1984). The areas of forest types in each reach and the weighting factors are shown in appendix 2.

Weighting factors were applied to average species composition data in each reach and results were combined for each forest type to yield the composition of forest types in the nontidal floodplain for each of the two 1976 sampling-methods sets. The two 1976 sampling-method sets were compared statistically using the Wilcoxon matched-pairs signed-ranks test to see if there were significant differences between the two sets. The number of trees sampled on cruise transects (1,401) was nearly equal to the number of trees sampled at thesis and ARQA intensive plots (1,429) (table 3). The weighted species compositions of the two 1976 sampling-methods sets were averaged together to yield the final 1976 species composition. Data from plots sampled in 2004 were averaged, weighted, and combined by the same methods as each 1976 sampling-method dataset. Forest type species composition was based on all available 1976 data (from 181 plots) and 2004 data (from 95 plots).

Table 3. Characteristics of three sets of data from forests of the Apalachicola River floodplain, Florida.

[Canopy trees are all trees with diameter at breast height (dbh) ≥ 7.5 centimeters (cm); subcanopy trees, dbh < 7.5 and ≥ 2.5 cm; ARQA, Apalachicola River Quality Assessment; <, less than; ≥, greater than or equal to]

Characteristic	1976 Data		2004 Data
	ARQA cruise transects	Thesis and ARQA intensive plots	
Number of transects	7	4	12
Number of plots	160 [a]	21	95
Area sampled, in hectares	na [a]	2.5	6.2
Number of canopy trees	1,401	1,429	3,572
Number of subcanopy trees	42 [b]	0	2,511
Number of species	38	40	47

[a] Cruise-transect data was sampled using a glass wedge prism at points without defined plot sizes.

[b] Not used in analyses.

Abundance of Tree Species throughout the Nontidal Floodplain

Total basal area and number of trees in the nontidal floodplain were calculated for 15 important tree species and for all other species combined using weighted data from all 1976 and 2004 plots. Data from forest types were combined in this analysis to assess the overall change in the abundance of species in the nontidal floodplain regardless of forest type. T-tests were used to test the significance of differences between the 1976 and 2004 weighted data and to determine the significance of differences between unweighted 1976 and 2004 basal area and density from the replicate plots for individual species.

Forest Types and Floodplain Species Categories

The changes in basal area and density from 1976 to 2004 for forest types and species grouped by FSCs were calculated using weighted data from the 71 pairs of replicate plots. The same analyses of basal area and density were repeated using unweighted data from the replicate plots, and statistics (t-tests) were calculated from unweighted replicate plot data.

Growth, Age, Mortality, and Recruitment from Thesis Data

Additional characteristics of tree species and forest types could be calculated and analyzed from the thesis data, because the locations of trees identified on 1976 thesis plots were recoverable for surviving trees in 2004. Growth rates, extrapolated tree ages, mortality rates, and recruitment rates for species and plots were used to understand the mechanisms of floodplain forest growth, structure, and replacement. Median ages (calculated from growth rates and extrapolated tree ages) of tree-size classes were also used to determine the length of time periods used in hydrologic analyses.

Individual growth rates were calculated for each tree by dividing the change in dbh from 1976 to 2004 by the number of elapsed years. The elapsed time differed slightly between the two transects, 27.5 years at BLT and 28.2 years at WEW.

Out of 462 surviving trees, 20 trees had negative growth and 11 trees had zero growth. All nonpositive growth rates were discarded because they generated an unusable value in the tree-age calculation (either an infinite age in the case of zero growth, or a negative age). Measurement errors could have occurred for a number of reasons. Most of the trees with negative growth rates had multiple trunks, and it was not possible to determine which trunk had been measured originally. Trees with attached vines or deformed trunks may not have been measured in the same way in 1976 and 2004.

It is possible that the wrong tree could have been identified and measured. For most trees on the thesis plots, the mapped location, the 1976 dbh, and the locations of surrounding species made misidentification highly unlikely; however, for a few trees there was more than one possible candidate.

Positive growth rates from 431 trees were averaged by species, and are presented in table 4 as supporting data used to develop methods described in the section “Hydrologic Time Periods Associated with Forest Sampling Groups.” Although growth rates of trees typically vary with age, the average growth rate for most species was based on a variety of tree sizes and ages. Growth rates could not be calculated for buttonbush, red mulberry, swamp privet, black willow, or water oak, because there were no surviving trees of these species, or for stiffcornel dogwood and chinaberry, which were species new to thesis plots in 2004.

The following formula was used to calculate extrapolated ages (summarized in app. 3) for each tree belonging to a species for which an average growth rate could be determined.

(dbh / (average annual growth rate for species)) + 5 years = extrapolated age, in years

The additional 5 years included in this formula is an estimate of the time necessary for a tree seedling to reach breast height and begin measurable diameter growth.

Growth rates calculated for some possum haw and persimmon trees were very slow, generating extrapolated ages as great as 560 years. To correct these assumed analysis errors, adjustments were made by capping all tree ages at a maximum of 360 years. This maximum age was based on the extrapolated age of the largest tree on the thesis plots, a bald

Table 4. Growth rates of tree species at the BLT and WEW transects on the Apalachicola River floodplain, Florida.

[Species growth rates were calculated from the average difference between measurements of diameter at breast height taken in 1976 and 2004 divided by the number of years elapsed between measurements. Negative or zero growth rates for individual trees were not included in the averaged rates. Scientific names of species are listed in appendix 1. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; cm/yr, centimeter per year; ≥, equal to or greater than; >, greater than; <, less than]

Species	Growth rate, in cm/yr (number of trees sampled)				General description of growth rate
	Forest type			Average	
	Hiblh	Loblh	Swamp		
sycamore	0.76 (2)	0.57 (4)		0.63	fast (≥ 0.5 cm/yr)
swamp laurel oak	0.31 (7)	0.65 (29)		0.58	
green ash	0.32 (6)	0.52 (22)	1.35 (1)	0.51	
water tupelo			0.50 (25)	0.50	
water hickory		0.46 (40)		0.46	above average (< 0.5 and ≥ 0.4 cm/yr)
sweetgum	0.41 (36)	0.48 (31)		0.44	
overcup oak	0.35 (3)	0.43 (28)	0.21 (1)	0.41	
river birch		0.41 (2)		0.41	
bald cypress		0.37 (8)	0.43 (13)	0.41	
Ogeechee tupelo		0.61 (4)	0.28 (13)	0.37	average (< 0.4 and ≥ 0.3 cm/yr)
water locust		0.32 (6)	0.46 (2)	0.35	
American elm	0.09 (3)	0.37 (12)	0.45 (3)	0.34	
red maple		0.26 (10)	0.29 (7)	0.27	below average (< 0.3 and ≥ 0.2 cm/yr)
hackberry	0.21 (8)	0.29 (28)		0.27	
winged elm	0.26 (5)			0.26	
ironwood	0.23 (12)	0.23 (13)		0.23	
popash			0.17 (11)	0.17	slow (< 0.2 cm/yr)
box elder	0.15 (4)			0.15	
planer tree		0.15 (24)	0.11 (1)	0.15	
green haw		0.06 (4)		0.06	
possum haw	0.04 (7)	0.02 (3)		0.04	
persimmon		0.03 (1)		0.03	
Average	0.31 (93)	0.40 (263)	0.39 (75)	0.38	

Figure 6. The largest tree in the 1976 and 2004 datasets was a bald cypress tree at the BLT transect in the upper reach of the Apalachicola River floodplain near Blountstown, Florida. Photograph taken by Lee Reed.

cypress at BLT (fig. 6). A total of 11 trees in 1976 and 3 trees in 2004 that exceeded the maximum age (all possum haw or persimmon) were given the maximum extrapolated age of 360 years (app. 3).

Median ages for canopy tree-size classes were the average of the median extrapolated ages in the 1976 and 2004 datasets (table 5). The extrapolated age of individual subcanopy trees could not be calculated because individual dbhs were not recorded. The median dbh of the subcanopy size class, 5 cm, and the average growth rate of all tree species on thesis plots, 0.379 centimeter per year (cm/yr), were used to determine one median age for all subcanopy trees using the formula:

$$\left(5 \text{ cm} / (0.379 \text{ cm/yr})\right) + 5 \text{ years} = 18 \text{ years}.$$

Mortality rates were calculated by first dividing the number of trees that died since 1976 by the original number of trees alive in 1976, using the combined data of both thesis transects. The result was then divided by the average number of years that elapsed between data-collection dates which was 27.85 years. Recruitment rates were calculated in a similar manner using the number of canopy trees that appeared in the 2004 data that were not in the 1976 data. Recruitment rates do not include subcanopy trees.

Comparisons of Forest Type Composition using Floodplain Indices

A primary objective of this study was to measure species composition change over time to determine if floodplain forests have shifted toward a drier mix of species. To accomplish this, a factor called the Floodplain Index (FI) was developed to classify forest plot data on a scale of relative dryness using a continuum from pure swamp (1.000) to pure upland (4.000) forest composition**.** Wentworth and others (1988) proposed the use of a similar type of index as a basis for wetland designation. It is important that the FI value for a plot not be confused with its forest type. FIs were used to measure changes in the relative dryness of the species composition, whereas forest types were determined from 1976 data using FSCs and rules for defining forest types (table 2). FI values were not used to determine forest types.

FIs for size classes at each plot were calculated by first multiplying the relative dominance of each species (based on rba for canopy trees and rd for subcanopy trees) by the FSC value for that species. All resulting values were then summed to determine the FI for the tree-size class of the plot. If 100 percent of the basal area of the canopy on a plot in 1976 was contributed by FSC2 species, the FI value for the 1976 canopy

Table 5. Median ages of tree-size classes in forests of the Apalachicola River floodplain, Florida.

[Median ages were calculated using the extrapolated ages of trees at the thesis sites (app. 3). Canopy trees are all trees with diameter at breast height (dbh) ≥ 7.5 centimeters (cm); large canopy trees, dbh ≥ 25 cm; small canopy trees, dbh ≥ 7.5 and < 25 cm; and subcanopy trees, dbh < 7.5 and ≥ 2.5 cm]

Tree-size class	Dataset	Number of tree samples	Median age, in years	Average median age, in years
canopy	1976	702	72	73.5
	2004	701	75	
large canopy	1976	222	95	99
	2004	270	103	
small canopy	1976	477	50	52.5
	2004	431	55	
subcanopy	2004	not applicable	18 [a]	18

[a] Extrapolated age for all subcanopy trees calculated from median dbh of 5.0 cm and average growth rate of all species at thesis sites.

of the plot would be 2.000 (100 percent x 2). If 50 percent of the basal area of the canopy of the same plot in 2004 was contributed by FSC2 species and 50 percent by FSC3 species, then the FI for the 2004 canopy of the plot would be 2.5 = ((50 percent x 2) + (50 percent x 3)). **A change of +0.500 in an FI value is a change of 50.0 percent of the composition toward the next drier forest type.** An example of the use of FIs to calculate change in composition at a hypothetical plot is given in table 6 where the change is +0.134 or 13.4 percent toward the composition of the next drier forest type.

FIs were used in two types of analysis to measure change in the relative dryness of species composition over time: changes in canopy species composition from 1976 to 2004 at replicate plots and comparisons between size classes to estimate past and future composition. In addition, the FI differences between size classes on the Apalachicola River floodplain were compared to those on five other north Florida stream floodplains. For all FI analyses, the Wilcoxon matched-pairs signed-ranks test was used to test for significance of differences. All probability (p) values that are < 0.1 are reported as significant in this report.

Changes in Floodplain Indices at Replicate Plots

Replicate plot analysis compared the FIs of 71 plots sampled in 1976 to the FIs of 71 plots sampled in 2004 which were located as nearly as possible at the original site of 1976 plots. In the case of 8 replicate plots at the thesis transects (BLT and WEW), 1976 plot locations were exactly recoverable in 2004. For parts of the thesis plots that were logged or otherwise altered between 1976 and 2004, the 1976 plot was limited to match the extent remaining in 2004. For example, part of the levee plot at BLT had eroded into the river by 2004, so the extent of the 1976 levee plot was reduced to match the remnant remaining in 2004. Restricting the 1976 data to remnant plots was necessary only for the replicate plot analysis. In the size-class analyses described below, FI values were calculated for all trees on the original plots.

Size-Class Comparisons as an Indicator of Past and Future Forest Composition

The size of trees roughly correlates to their comparative age, because dbh increases with age. Trees in mature forests are constantly dying and being replaced by younger, smaller trees. Ultimately, all replacement canopy trees come through the ranks of sizes from seedling to sapling to subcanopy tree to canopy tree.

Trees were grouped by their dbh into two major size classes: canopy trees (dbh ≥ 7.5 cm), and subcanopy trees (dbh < 7.5 and ≥ 2.5 cm). The term “canopy tree” in this report is based solely on dbh without regard to over- or under-story tree height. Canopy trees were further subdivided into large canopy trees (dbh ≥ 25 cm) and small canopy trees (dbh < 25 and ≥ 7.5 cm). There were no subcanopy data available for the thesis and ARQA intensive plots. Although the dbh of trees was recorded on ARQA cruise-transect plots, size-class analyses were not performed on cruise-transect data, because size classes from the same plot extent were not available for data collected using the glass wedge prism method.

The composition of the 1976 large canopy tree-size class is the best representation of forest composition before water levels began to decline in 1954. The 1976 large canopy trees were probably seedlings or root sprouts in the late 1800s, and most of their lives were spent in the hydrologic conditions that existed before 1954. Forests in 2004 contained large canopy trees that were established prior to 1954, but they also contained some younger trees that had lived the greater part of their lives in the hydrologic conditions that had occurred since 1954.

Table 6. Use of the Floodplain Index to calculate change in composition of forest plots in the Apalachicola River floodplain, Florida.

[The Floodplain Index (FI) is the total of the relative basal areas (rba) of canopy tree species weighted by Floodplain Species Category (FSC). See table 2 for a definition of FSC and appendix 1 for a list of scientific names and FSCs for each species. A change of + 0.01 in the FI is a change of 1 percent of the species composition to a drier forest type]

Calculation of FI values for change in a hypothetical floodplain forest plot:

1976 Composition				2004 Composition			
Species	Rba, in percent	FSC value	FI value	Species	Rba, in percent	FSC value	FI value
water hickory	40.0	2	0.800	water hickory	26.6	2	0.532
American elm	2.6	2	0.053	American elm	2.6	2	0.053
hackberry	10.0	3	0.300	hackberry	23.0	3	0.689
sweetgum	17.0	3	0.510	sweetgum	19.9	3	0.598
box elder	14.9	3	0.446	box elder	14.9	3	0.446
water oak	2.4	3	0.071	water oak	2.4	3	0.071
persimmon	1.8	3	0.055	persimmon	1.8	3	0.055
possum haw	3.0	3	0.090	possum haw	0.5	3	0.014
winged elm	8.3	4	0.331	winged elm	8.3	4	0.331
Total	100.0		2.656	**Total**	100.0		2.790

Change in composition from 1976 to 2004 is the difference in FI values at a hypothetical floodplain forest plot:

2004 FI	2.790
1976 FI	2.656
Difference	+0.134

The difference of + 0.134 can be stated as a change of 13.4 percent of the species composition toward a drier forest type.

The subcanopy tree-size class reflects the most recent hydrologic conditions, because this size class contains the greatest percentage of young trees. Present subcanopy composition can be used as an indicator of future canopy composition, because older trees will eventually be replaced by the younger trees growing in today's subcanopy, assuming future hydrologic conditions remain similar to conditions that have occurred recently. Some subcanopy species will never grow into canopy trees, but those species can serve as indicators of hydrologic conditions equally as well as canopy tree species. For example, possum haw, a species of limited size potential, was commonly sampled on 1976 Hiblh plots and was not present on 1976 swamp plots. The presence of possum haw in a swamp subcanopy in 2004 could indicate drier hydrologic conditions at the site and a drier canopy composition in the future, even though possum haw will never grow large enough to be a dominant tree by basal area in the canopy.

Size-class analyses were conducted for each forest type and reach by comparing the FI values for the large canopy, small canopy, and subcanopy size classes to the FI value for the canopy trees. For example, if the large canopy tree-size class had a lower FI value than the FI value for the composition of canopy trees, the difference may indicate that hydrologic conditions at the site were generally wetter during an earlier period of time (when establishment and growth of the large canopy trees occurred) than conditions were during the more recent past (when the smaller canopy trees became established and grew). If subcanopy trees had drier FIs than canopy trees, the site probably experienced drier hydrologic conditions in the most recent years, and the canopy will probably have a drier species composition in the future.

Size-Class Comparisons on Other North Florida Stream Floodplains

Forest data from studies conducted on five other north Florida streams (Light and others, 1993; 2002) were compared with results of the current study to determine if the differences in FIs between size classes determined on the Apalachicola River floodplain are typical for north Florida streams. This analysis used a total of 16 transect sections (hereafter called plots) on six nontidal transects on the Suwannee River floodplain with all three forest types (Hiblh, Loblh, and swamp) well represented, a total of nine plots at three sites on the Ochlockonee River floodplain with all three forest types represented at each site, two Loblh plots on the Aucilla River, two Loblh plots on the St. Marks River, and two swamp plots on the Telogia Creek floodplain.

All forest types on these five stream floodplains were redetermined for this analysis following the rules used in the current study (table 2). The size limits of canopy and subcanopy trees originally used on the five other streams were different from that used in the current study; canopy trees had a dbh ≥ 10 cm and subcanopy trees had a dbh < 10 cm. In this analysis, forest data from Apalachicola River floodplain plots were reorganized using these size limits to allow comparisons with the forest data from the other stream floodplains.

Statistical analysis of the differences in FIs between size classes was conducted for all plots combined (regardless of forest type) on both the Suwannee and Ochlockonee River floodplains, but not for plots on the other stream floodplains because sample sizes were too small. In the summary analysis, the differences in FI values between size classes in all 31 plots on the five other streams were averaged together and then compared with the differences in FIs between size classes on all 2004 plots in the Apalachicola River floodplain.

Analysis of Hydrologic Data

The primary goal of the hydrologic analyses was to quantify and summarize long-term hydrologic changes at floodplain forest plots so that they could be compared to changes in forest composition. Most of the basic hydrologic data used in this report came from ongoing data-collection programs of the USGS, USACE, and National Weather Service (NWS) that were conducted independent of this study. The following methods describe the steps required in determining the amount of hydrologic change by forest type and reach.

History of Inundation at Forest Plots

The history of inundation at floodplain forest plots was estimated using discharge and stage records collected at a long-term streamflow gaging station (gage) located at the upper end of the study area, Apalachicola River at Chattahoochee (02358000), and from stage records collected at five downstream gages, Apalachicola River near Blountstown (02358700), Apalachicola River near Wewahitchka (02358754), Apalachicola River at River Mile 36 (023587547), Apalachicola River at River Mile 35 (023587549), and Apalachicola River near Sumatra (02359170). The following short names are used in this report for these six gages: Chattahoochee, Blountstown, Wewahitchka, RM 36, RM 35, and Sumatra. Information about gage locations, operating agencies, and period of record at each gage is summarized in a previous report (Light and others, 2006) along with a detailed description of a nonstandard approach for relating discharge at the Chattahoochee gage to stage at all downstream gages. Nonstandard stage-discharge relations were used because traditional stage-discharge relations were not available for most of the downstream gages, and comparisons among many different sites along the river were greatly simplified by calculating stage at all locations in relation to discharge at a single upstream site (Chattahoochee gage).

In forest-hydrology studies, the longest possible period of record is preferred, because tree ages can easily be 100 years or older. The 76-year period of record at the Chattahoochee gage (October 1, 1928, to September 30, 2004) used by Light and others (2006) represents the period during which the gage was serviced by the USGS. Earlier stage data at the Chattahoochee gage extending back to January 1920 (collected by the NWS) was examined for possible use in the present study. Earlier stage data also existed at the Blountstown gage (collected by the USACE). Stage data prior to October 1, 1928, at both gages (Chattahoochee and Blountstown) were converted to Chattahoochee discharge using stage-discharge relations developed for the 1928-54 period in appendix I and II of Light and others (2006). Chattahoochee discharge estimated from the Chattahoochee stage were similar to Chattahoochee discharge estimated from the Blountstown stage for records extending back to July 1, 1922. Prior to that time, however, discharge data at these sites did not match, suggesting that stages were incorrect at one of the two sites. Thus, data prior to July 1, 1922, were considered unusable, and data used in the present study began October 1, 1922 (to coincide with the beginning of the next water year). The endpoint of the period of record used in the present study was extended to December 31, 2004, so that 82 years of complete record were available for three types of annual analyses: water year (October 1-September 30), calendar year (January 1-December 31), and growing season (March 1-November 24).

The first step in estimating inundation history at the forest plots involved filling in the missing records at the five gage sites for October 1, 1922, to December 31, 2004. All missing records were estimated and a complete set of daily values was created for discharge at the Chattahoochee gage and stage at all gages except RM 36. Of the 30,043 total days in this 82-year period of record, Chattahoochee stage had the least missing record (159 days) and RM 35 stage had the most (26,346 days). Methods for estimating records were based on: (1) actual data for the closest gages where records were available, (2) pre-dam and recent stage-discharge relations modified from appendixes I-V in Light and others (2006), and (3) the general timing of stage decline in periods between pre-dam and recent as depicted in figure 5 of Light and others (2006). The number of days of missing record, water years during which missing records occurred, and detailed methods used to estimate missing records are summarized in appendix 4.

In the next step, a complete set of daily river stage values for the 82-year period of record was estimated for the rm location of each transect. Transect stage records were primarily estimated using linear interpolation between stages at the closest upstream and downstream gages. In some cases, however, transect stages could not be estimated directly from linear interpolation between gages, because water-surface profiles in figure 9 of Light and others (2006) indicated that water surfaces at some transects differed from those that would be expected with straight-line interpolation. In those cases, pre-dam and recent stage-discharge relations specific for the transect locations (from the compact disc in the map pocket of Light and others, 2006) and assumptions regarding the degree and timing of channel changes at transect locations in the intervening period (between pre-dam and recent) were used to estimate transect stage records. Details of the methods used to estimate stage records at each transect are described in appendix 5.

In the last step, the inundation history at individual forest plots along each transect was estimated based on river stages in the 82-year period of record at transect locations. The ground elevation of each forest plot was compared to daily river stage and the plot was considered to be inundated every day that the river stage exceeded the plot elevation. The plot was not considered inundated when river stage was the same as, or less than, the plot elevation. Plot elevations for ARQA transects (CH, TO, SE, OR, MR, PL, and BR) were available from USGS files (Tallahassee, Florida) that were used to develop figure 34 in Leitman and others (1984). Plot elevations for BLT and WEW were available in Leitman (1978). Plot elevations at EA, EB, and EC reported by Eichholz and others (1979) were incorrect, and were resurveyed in 2006 by the authors of this report.

Water levels in most bottomland hardwood forests can be estimated accurately from stage records in the adjacent river channel. Water levels in many swamps, however, are not directly related to river stage levels. This issue is discussed at length, with examples from selected transects, in a later section of the report titled “Hydrologic Conditions in Floodplain Forests.”

Hydrologic Time Periods Associated with Forest Sampling Groups

River flow at the Chattahoochee gage and river stage at all transects and forest plots were analyzed for five time periods associated with tree-size classes of the 1976 and 2004 forest sampling data. If unlimited hydrologic records had been available, the ideal time periods for hydrologic analysis would have been the same number of years as the median ages of trees in the various size classes (table 5). River flow and stage records, however, were not available prior to October 1, 1922. The maximum length of hydrologic record available for 1976 canopy trees of 54 years (1923-76) was the limiting factor in determining time periods for all of the forest sampling groups.

The median age of the large canopy trees (99 years, table 5) was selected as the most relevant age to species composition of canopy trees, because the large canopy trees contributed more than 80 percent of the total basal area of all canopy trees in both the 1976 and 2004 datasets. The available hydrologic record of 54 years for the 1976 canopy trees was divided by the median age of large canopy trees of 99 years. The result, 54.5 percent, was used as a proportion to be applied to the hydrologic records of the other four tree groups to allow for equitably balanced comparisons between groups. This proportion, 54.5 percent, was multiplied by the median age of small canopy trees and the median age of subcanopy trees to determine an appropriate length of hydrologic records in each case (29 years of record for small canopy; 10 years for subcanopy). The final time periods for hydrologic analysis are shown in figure 7.

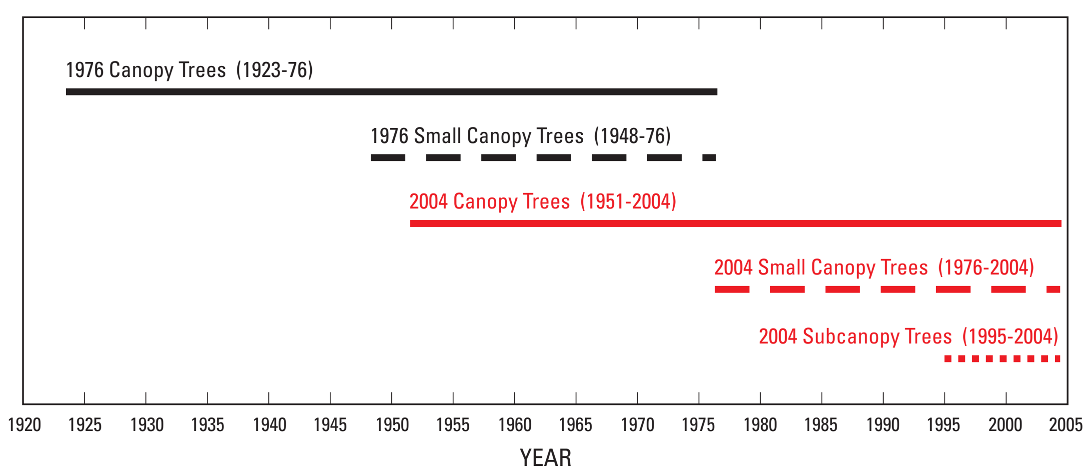


Figure 7. Hydrologic time periods associated with 1976 and 2004 tree-size classes in forests of the Apalachicola River at Chattahoochee, Florida.

Because the period of record was limited to 54.5 percent of the median age of each tree-size class, the dryness of the hydrologic periods associated with these five forest groups is somewhat exaggerated. Recent water levels are lower than earlier water levels, as indicated in figure 4 and in a previous study (Light and others, 2006). Limitations inherent in the methods for selecting these five time periods should be kept in mind as results are presented.

Flood Duration, Depth, and Frequency by Forest Type and Reach

The inundation history during each year of the five hydrologic time periods was used to calculate the following hydrologic parameters for all forest plots in the 1976 and 2004 datasets: (1) flood duration during the whole year, in days (not necessarily consecutive); (2) flood duration during the growing season (March 1-November 24), in days (not necessarily consecutive); (3) flood depth, in meters, of the highest annual flood lasting 14 consecutive days in the growing season; and (4) flood frequency, in percent of years with a flood lasting 14 consecutive days in the growing season. Means were used to summarize flood duration and frequency values, but medians were preferred for summarizing flood depths, because in bottomland hardwood plots, flood depths were zero in many years. Data at each plot were combined by forest type and reach, yielding separate datasets covering all combinations of the following groups: three forest types, three reaches, five hydrologic time periods, and four hydrologic parameters. Box-plot graphs of the median, 25th and 75th percentile, minimum, and maximum values for most of the datasets in the earliest time period (1923-1976) were created to illustrate the natural or "baseline" hydrologic conditions in floodplain forests.

Statistical tests (Pearson's r coefficients) indicated that flood depth, flood frequency, and both types of flood durations were highly correlated with each other. This result was expected, because all hydrologic parameters were calculated from the same basic river stage data. A single parameter, flood duration in the growing season, was selected to simplify subsequent analyses of hydrologic change in floodplain forests. Flood durations have been used by the authors as a primary descriptor of forest hydrology in previous reports (Light and others, 1993; 2002).

Methods for calculating hydrologic change in this report were modeled after the methods for determining change in forest composition to allow for direct comparisons. In both cases, change was measured as a percentage of change toward the next drier forest type. Hydrologic change for a given forest type is based on flood durations in the growing season and is expressed in terms of the percentage of change of flood duration toward the baseline (1923-76) duration of the next drier forest type. It is calculated using the following formula where X is a given forest type and Y is the next drier forest type:

$$\frac{\text{(Flood duration of X in earlier period)} - \text{(Flood duration of X in later period)} * 100}{\left(\text{(Flood duration of X in baseline period)} - \text{(Flood duration of Y in baseline period)}\right)} = \text{Change in flood duration toward duration of next drier forest type, in percent.}$$

Flood durations were assumed to be zero for uplands, the next drier forest type for Hiblh forests.

Changes in Hydrology and Forest Composition

Changes in hydrologic conditions at floodplain forest transects were estimated from long-term streamflow gaging station records and summarized for time periods associated with various trees-size classes. Changes in forest composition were calculated using several quantitative measures of composition and some comparative field observations. The relations between hydrologic conditions and forest composition were examined and future changes that are expected to occur in the floodplain forest are discussed.

Hydrologic Change

Long-term river discharge and river stage were examined for trends that might result in change in forest composition. Water levels in the floodplain are similar to those in the main river channel during high flows greater than 1,420 m^3/s (50,000 ft^3/s), but the relation between river and floodplain hydrology during low-flow periods can be complex, depending upon individual site conditions. Duration, depth, and frequency of inundation at floodplain forest plots, based on long-term river-stage data in the adjacent main channel, were summarized by forest type and reach.

River Flow and Stage

In large river floodplains, inundation resulting from overbank flooding is usually the most important factor influencing forest composition (Greeson and others, 1979; Gosselink and others, 1990; Lugo and others, 1990; Carter, 1996). Both river flow and stage must be considered in understanding patterns of floodplain inundation. Flow in the Apalachicola River is primarily controlled by conditions upstream from the Chattahoochee gage, where about 90 percent of the ACF drainage basin lies. River stage is a function of river flow and geomorphic conditions in the river channel locally.

Long-term averages of river discharge and river stage at the Chattahoochee gage are compared in figure 8. Based on 10-year running averages, river discharge shows little change, but river stage has been declining since the 1950s. Channel enlargement caused by erosion of the riverbed and banks at the Chattahoochee gage explains why average stage has declined but average discharge at the same location has not.

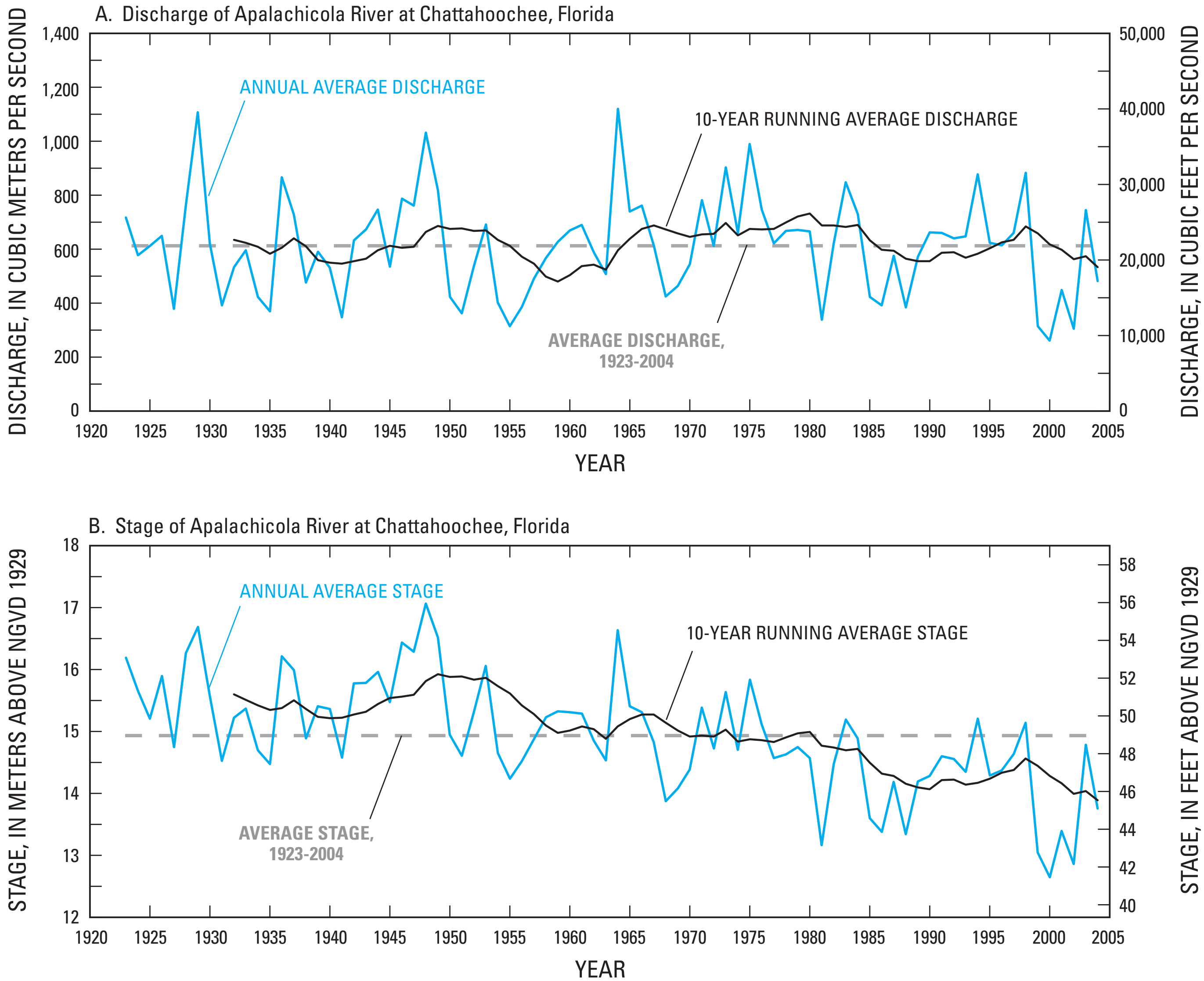


Figure 8. Discharge and stage of the Apalachicola River at Chattahoochee, Florida.

Monthly analysis of river discharge shows a seasonal decline that is not evident in the analyses of long-term annual averages. Figure 9 shows river discharge averaged by month during the five hydrologic time periods associated with tree-size classes. River discharge in spring and summer has decreased, particularly in April through August. This seasonal pattern is consistent with that of a previous analysis using different time periods (Light and others, 2006) when spring and summer flows decreased from an earlier 30-year period (1929-58), predating flow regulation and large increases in water use in the ACF basin, to a later 30-year period (1975-04) that included those effects. In that study, decreases in spring and summer flows were greatest during drought conditions (defined as the lowest 10 percent of flows).

Monthly analyses of hydrologic data are essential in biological studies in floodplains because life cycle requirements of most biota depend upon seasonal hydrologic conditions. The preferred time period for assessing the influence of hydrology on floodplain forest communities is the local growing season, because inundation has little effect on tree growth and survival during the dormant season. Spring and early summer, in particular, are the seasons of greatest tree growth (Conner and Day, 1992), and are probably the seasons when flooding has the largest influence on tree composition and recruitment in floodplain forests.

Large declines in river stage during the growing season have occurred at nearly all locations in the nontidal river (fig. 10). The declines were caused by a combination of

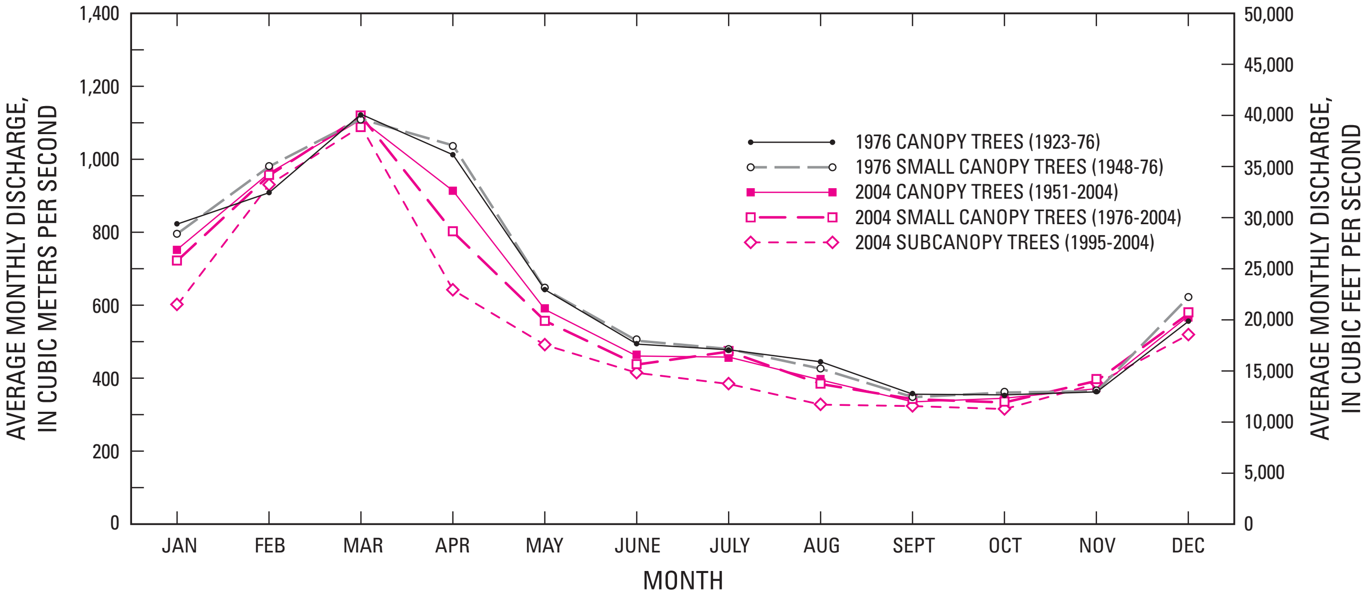


Figure 9. Average monthly river discharge during five hydrologic time periods associated with 1976 and 2004 tree-size classes in forests of the Apalachicola River floodplain, Florida.

channel enlargement locally and decreased spring and summer flows delivered from upstream. The largest declines have occurred at locations with the greatest channel enlargement (CH just downstream from the dam and EC in the reach where the most channel straightening occurred). Decreased flows in the spring and summer, as shown in figure 9, have added to water-level decline at all locations. When drought conditions prevail, decreased flows are the primary cause of water-level declines at many locations along the river during April, May, July, and August (fig. 4).

Hydrologic Conditions in Floodplain Forests

During the flood season, water levels in the floodplain are similar to river levels in the adjacent main channel. During the low-water season, the relation between river stage and floodplain hydrology is affected by individual site characteristics, such as elevation and topographic position within the landscape, amount of water delivered from adjacent uplands through small streams or bluff seepage, efficiency of sloughs or other drainage features in removing water from the site, and the effect of beaver dams in floodplain sloughs downstream from the site. These local site characteristics can substantially affect the hydrology of swamps that are disconnected from the river by intervening levees and ridges. Hydrologic conditions in bottomland hardwood forests, however, are less affected by local site characteristics, because water connections between the river and the floodplain are generally unimpeded when water levels reach these higher-elevation forests.

Two examples shown in figure 11 illustrate the variability of the relation between river stage and water levels in swamps of the Apalachicola River floodplain during typical low-flow conditions in the summer. At the PL transect (graph A of fig. 11), sloughs that drain the swamp forests are directly connected to the river about 0.8 km downstream, allowing water from the river to enter and exit swamps unimpeded by intervening levees or ridges. Consequently, swamp water levels at PL are at the same elevation as river levels in the adjacent main channel. A decline of 0.9 m in typical summer water levels in both the river and the swamp has resulted in severe summer dewatering of swamp forests at this site. Based on transect distances shown in graph A of figure 11, more than 90 percent of the land surface covered by standing water in the earlier period was exposed with no surface water present in the later period.

Water levels in the SE swamp in graph B of figure 11 were elevated 2.6 m above river levels during typical summer conditions in the later period (1995-04). This perched basin receives year-round seepage water from an adjacent upland bluff, and the swamp stays wet because the basin has a flat, shallow-bowl shape and has only a few small outlet sloughs that are often impounded by beaver dams. In spite of the fact that continuous seepage from the upland bluffs and beaver dams have protected this basin from completely drying out, progressive lowering of river levels appears to have dewatered large areas of this swamp. Bed scour in the Apalachicola River has progressed into the mouth of a slough draining this swamp basin at its downstream end, lowering the elevation of the threshold where water is retained throughout the entire swamp. (Similar conditions at the mouths of sloughs draining other upper-reach swamps were observed by the authors in the 1990s.) Based on transect distances shown in graph B of figure 11, more than 75 percent of the land surface covered by standing water in the earlier period was exposed with no surface water present in the later period.

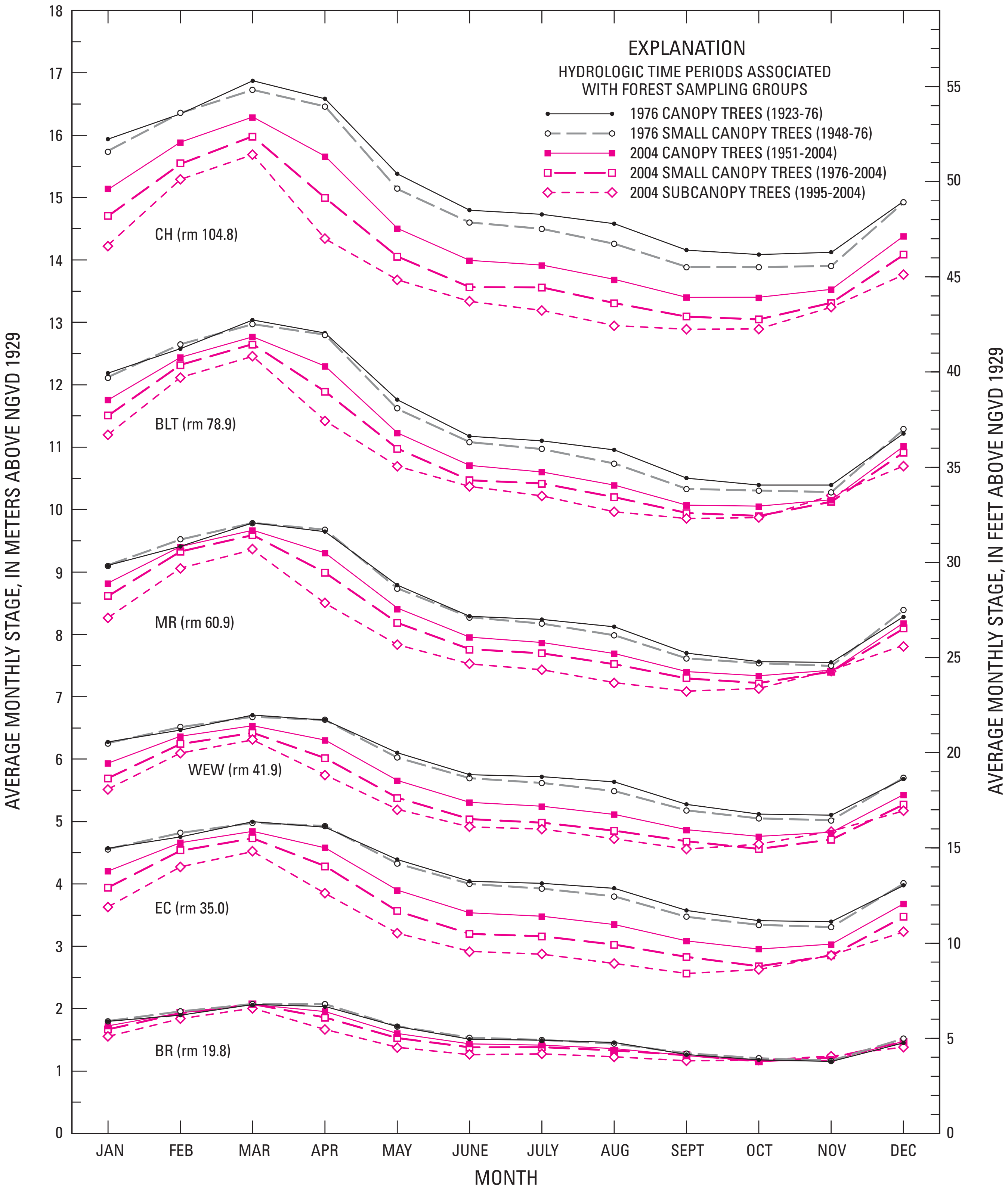


Figure 10. Average monthly river stage at selected transects during time periods associated with 1976 and 2004 tree-size classes in forests of the Apalachicola River floodplain, Florida. Data were averaged from 1923-04 daily stage records which were estimated at each transect from long-term gage data as described in the Methods section.

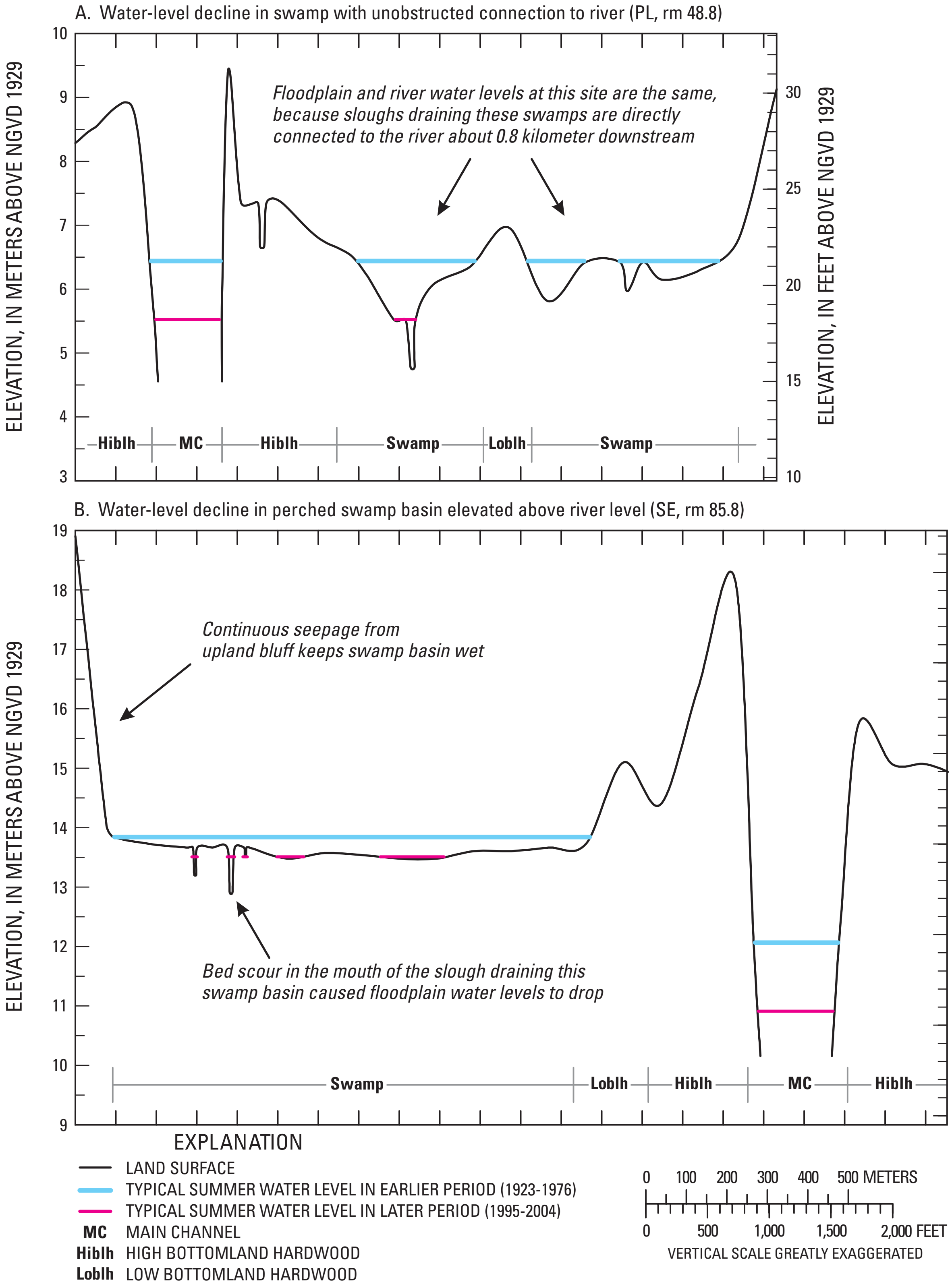


Figure 11. Decline in summer water levels in two different types of swamps and in the adjacent main channel at selected transects of the Apalachicola River floodplain, Florida. Summer water levels in the main channel are the average July river stage for the earlier period (1923-76) and the later period (1995-04), estimated from long-term records at nearby gaging stations. Summer water levels in the swamps were estimated for the earlier period based on 1979-80 field observations and for the later period based on 2004-06 field observations.

Another variation in river-floodplain relations, not shown in figure 11, occurs at the BR transect at the downstream end of the nontidal reach (rm 19.8). The west end of this transect intersects Brothers River (fig. 2), a large tidal stream with summer water levels typically about 1 m lower than Apalachicola River levels. Forest sampling data from the east end of this transect are used in this report because that part of the transect is nontidal. Swamps on the nontidal part of the transect, however, drain westward to a creek that is connected to Brothers River, so summer water levels in these swamps are usually 0.3-0.6 m lower than Apalachicola River levels. Because of these unique site conditions at BR (not found on any other nontidal transect), water-level data in the Apalachicola River considerably overestimate inundation in the adjacent swamp. Conditions at BR are the opposite of those at SE (fig. 10B), where water-level data in the river considerably underestimate inundation in the adjacent swamp.

Comparisons of water levels in swamps with those in the adjacent main channel at other locations in the Apalachicola River floodplain (Leitman, 1978; Leitman and others, 1984) confirm that hydrologic relations between swamps and the river can differ considerably from site to site. Various water-level observations made in swamps over the years have been helpful in understanding the connections between the river and floodplain, but because most of those observations have been infrequent and discontinuous, they are not sufficient for estimating long-term water levels in swamps during the five time periods associated with tree-size classes (fig. 7). Consequently, floodplain conditions are estimated in this report based only on river-stage data, without any modifications to account for site-to-site variability in swamp characteristics. These estimates are highly accurate in Hiblh forests and most Loblh forests, somewhat less accurate in Loblh forests near swamp depressions that retain water, and least accurate in swamps that lack a direct connection to the river. The limitations of these estimates are discussed later in this report, and should be carefully considered by readers if they use these data for any other purposes. When measuring change from earlier to later periods, however, the example in figure 11B demonstrates that estimates based on river stage can be useful indicators of the water-level decline that has occurred in swamps, in spite of complicating site-specific variables, such as outside sources of water or differences in drainage outlets.

Flood duration, depth, and frequency, based on long-term river-stage data (1923-76), were calculated for floodplain forest plots and summarized by forest type and reach (fig. 12). Flood duration was calculated for the whole year and the growing season, whereas depth and frequency were calculated based only on the growing season data. Hydrologic conditions, based on the 1923-76 period in figure 12, represent natural "baseline" hydrologic conditions for 1976 floodplain forests. Although the 1923-76 period includes 23 years of post-1954 channel erosion caused by dam construction and navigational improvements, higher than normal discharges during many years in the 1960s and 1970s (fig. 8A) masked some of the effects of channel change during those two decades (fig. 8B).

Within a given reach, flood duration, depth, and frequency are always the least in Hiblh forests and the greatest in swamps. For a given forest type, hydrologic conditions are usually driest in the upper reach and wettest in the lower reach, with the exception of flood depth. Depth of flooding usually decreases in the lower reaches of coastal plain rivers because floodwaters spread out onto wide, flat floodplains as rivers approach sea level near the coast.

Forest Composition Change

Basal area and density of species based on 1976 and 2004 data from all plots were used to compare the species composition of 1976 and 2004 forest types and the total basal area and number of trees in the nontidal floodplain. Basal area and density for forest types and species grouped by FSCs were calculated using data from the replicate plots. Data on individual trees that were unique to the thesis plots were used to describe growth rates, size, recruitment, and mortality of floodplain trees. Changes in composition to drier or wetter forests were quantified with FIs of replicate plots and 1976 and 2004 tree-size classes, and compared to forests on five other north Florida stream floodplains.

Species Composition of Forest Types

The species composition of forest types as basal area and density of species is presented in tables 7 and 8, respectively, and as rba and rd in appendixes 6 and 7, respectively. Basal area and density values were calculated from all the 1976 and 2004 plot data (276 plots) and weighted to compensate for reach differences. "Dominant species" (shown in bold) are those species with the highest values of basal area or density that make up 50 percent or more of the total basal area or density. A comparison of dominant species for 1976 to 2004 forest types is presented in table 9.

Species composition derived independently for the two 1976 sampling-method sets (ARQA cruise-transect data and combined thesis and ARQA intensive-plot data) are shown in tables 7 and 8 and appendixes 6 and 7 to allow a comparison of results obtained using two different sampling methods: (1) prisms (on cruise transects), and (2) intensive-plot sampling (on thesis and ARQA intensive plots). Basal area and density of species on the cruise transects were significantly correlated to values calculated for the combined thesis and ARQA intensive plots (Pearson's $r > 0.56$, $p < 0.001$ for basal area; Pearson's $r > 0.57$, $p < 0.002$ for density) despite the difference in methods used to obtain data. Total basal areas and densities of forest types were not consistently higher or lower for either 1976 sampling-method set.

Sweetgum and hackberry were dominant species by basal area in 1976 and 2004 Hiblh forests (table 9). In 2004, water oak was also a dominant species in Hiblh forests. Dominant species by basal area in Loblh forests were the same four

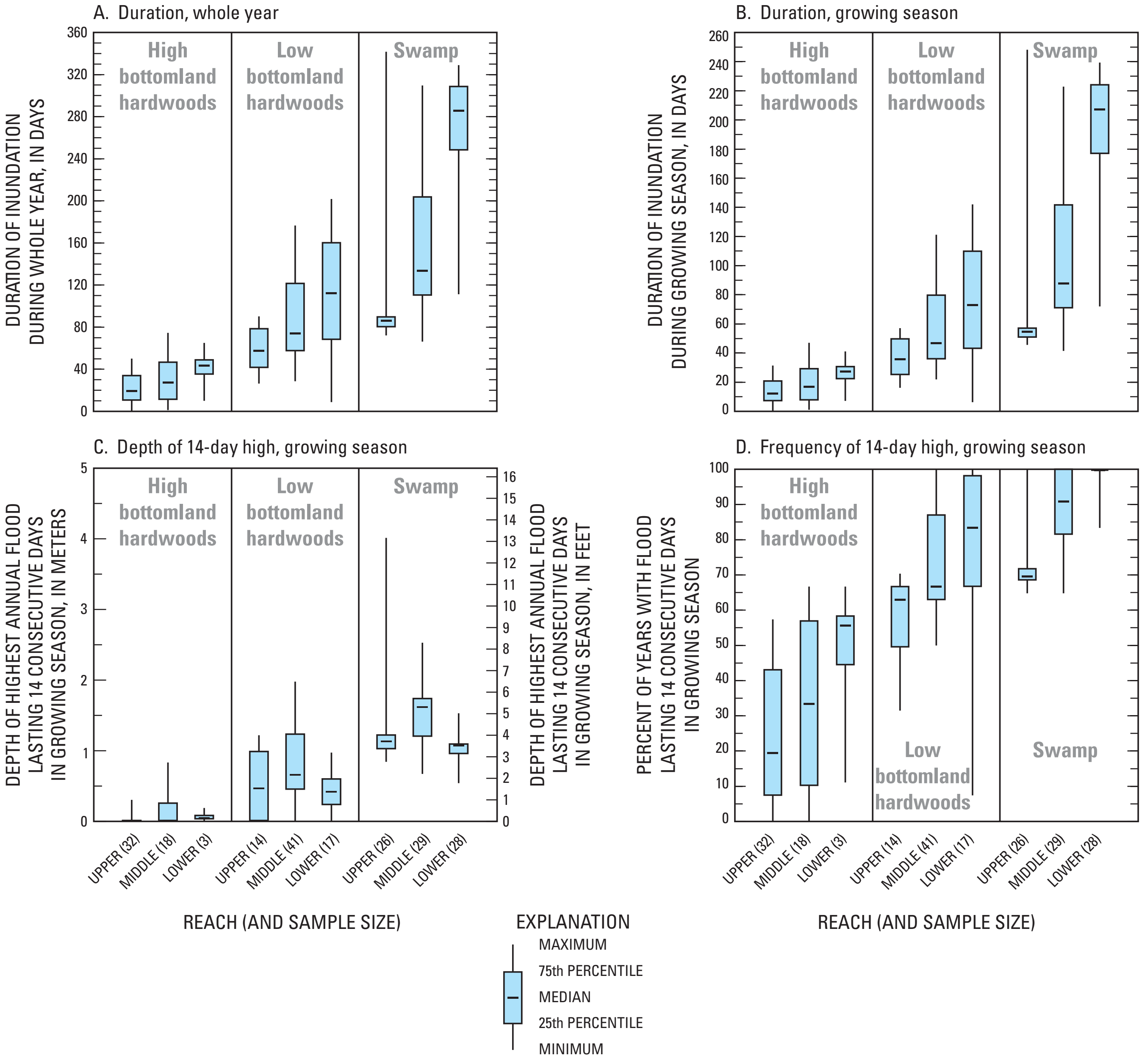


Figure 12. Duration, depth, and frequency of flooding summarized by forest type and reach in the Apalachicola River floodplain, Florida, for 1923-76. All values were calculated directly from stage in the adjacent river channel without any adjustments for water retention in depressions or other factors affecting the relation between river stage and floodplain water levels.

species in 2004 as in 1976 (water hickory, overcup oak, swamp laurel oak, and green ash), and in swamps, the same two species, water tupelo and bald cypress.

Species dominance by density changed more than dominance by basal area between 1976 and 2004 (table 9). Sweetgum and ironwood remained dominant canopy trees in 2004 Hiblh forests, but possum haw declined in canopy density in Hiblh forests and was not a dominant Hiblh tree in 2004. Water oak and hackberry were new dominants in 2004 Hiblh forests. Possum haw increased in density in 2004 Loblh forests and was a new dominant in 2004 Loblh forests along with two additional FSC3 species, hackberry and sweetgum. Overcup oak, green ash, and river birch (all FSC2 species) that were dominant in 1976 Loblh forests, declined in density and were no longer dominant in 2004 Loblh forests. Dominant species by density in 1976 swamps did not change although the average density of the dominant species declined (table 8C).

Table 7. Basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Basal area, in square meters per hectare (m^2/ha), was weighted by the percent of area of each forest type in each reach. The sum of the basal area of the most dominant species (**in bold**) is greater than 50 percent of the total basal area. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Basal area, m²/ha			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
A. High bottomland hardwoods					
sweetgum	3	**7.69**	**14.13**	**9.32**	**9.13**
hackberry	3	**4.62**	2.76	**4.22**	**3.57**
ironwood	3	**2.79**	0.45	2.26	1.23
water oak	3	2.76	0.23	2.17	**3.18**
green ash	2	1.30	3.46	1.96	1.27
swamp laurel oak	2	0.99	0.97	1.02	0.96
American elm	2	1.00	0.47	0.97	1.96
possum haw	3	0.77	0.48	0.82	0.17
swamp chestnut oak	3	0.77		0.72	0.31
water hickory	2	0.52	1.92	0.71	1.40
sycamore	3	0.69	1.24	0.66	0.64
box elder	3	0.48	0.49	0.53	0.72
swamp privet	2	0.32	0.05	0.33	
overcup oak	2	0.24	0.40	0.30	0.38
red maple	2	0.19	0.37	0.22	0.21
red mulberry	3	0.23	0.07	0.13	0.08
Chinaberry	4	0.13	0.30	0.13	0.19
winged elm	4	0.17	0.06	0.10	0.58
pagoda oak	3	0.16		0.08	
green haw	2	0.09	0.07	0.06	0.01
swamp tupelo	1	0.09		0.05	0.48
spruce pine	3	0.09		0.05	
bald cypress	1	0.08		0.04	
black tupelo	4	0.08		0.04	
slippery elm	4	0.08		0.04	0.10
buckthorn bumelia	3	0.05		0.02	0.04
loblolly pine	4	0.05		0.02	
persimmon	3		0.07	0.02	0.24
river birch	2		0.06	0.01	0.24
black walnut	4		0.03	0.01	
American holly	3				0.69
bitternut hickory	3				0.47
Southern magnolia	4				0.08
silverbell	4				0.08
planer tree	1				0.03
Ogeechee tupelo	1				0.02
Chinese tallow tree	3				0.01
cherry laurel	4				0.01
popash	1				0.005
Average total basal area, in m²/ha		26.4	28.1	27.0	28.5
Number of trees sampled		352	283	635	671
Total area sampled, in ha		na	0.49	na	1.22
Number of species		27	21	30	30

Table 7. (Continued) Basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Basal area, in square meters per hectare (m^2/ha), was weighted by the percent of area of each forest type in each reach. The sum of the basal area of the most dominant species (**in bold**) is greater than 50 percent of the total basal area. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Basal area, m^2/ha			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
B. Low bottomland hardwoods					
water hickory	2	**2.99**	**7.53**	**5.26**	**5.73**
overcup oak	2	**5.77**	2.46	**4.11**	**3.43**
swamp laurel oak	2	1.95	**4.53**	**3.24**	**3.39**
green ash	2	**3.03**	**3.25**	**3.14**	**2.79**
American elm	2	**3.31**	0.94	2.12	2.15
river birch	2	**2.84**	0.98	1.91	1.37
Ogeechee tupelo	1	2.46	0.91	1.68	1.69
sweetgum	3	1.89	0.92	1.41	2.06
hackberry	3	0.98	1.14	1.06	1.37
water tupelo	1	1.30	0.34	0.82	1.35
ironwood	3	0.76	0.74	0.75	0.51
red maple	2	0.77	0.34	0.55	0.81
bald cypress	1	0.27	0.62	0.44	0.89
water oak	3	0.33	0.43	0.38	0.10
black willow	1		0.65	0.33	
popash	1	0.41	0.24	0.32	0.20
planer tree	1	0.15	0.50	0.32	0.31
water locust	2	0.09	0.30	0.20	0.57
possum haw	3	0.05	0.26	0.15	0.26
sycamore	3	0.15	0.11	0.13	0.27
green haw	2	0.14	0.08	0.11	0.04
box elder	3	0.14	0.02	0.08	0.17
laurel oak	4	0.03	0.13	0.08	
swamp cottonwood	1	0.15		0.08	0.23
swamp chestnut oak	3	0.09		0.05	
swamp privet	2	0.06	0.02	0.04	0.02
persimmon	3	0.05	0.01	0.03	0.08
swamp tupelo	1	0.05		0.02	
black tupelo	4	0.03		0.01	
buttonbush	1		0.0003	0.0002	0.08
sweetbay	3				0.04
red mulberry	3				0.02
stiffcornel dogwood	2				0.01
Average total basal area, in m^2/ha		30.2	27.4	28.8	30.0
Number of trees sampled		409	602	1,011	1,319
Total area sampled, in ha		na	1.31	na	2.55
Number of species		28	26	30	28

Table 7. (Continued) Basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Basal area, in square meters per hectare (m²/ha), was weighted by the percent of area of each forest type in each reach. The sum of the basal area of the most dominant species (**in bold**) is greater than 50 percent of the total basal area. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Basal area, m²/ha			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
C. Swamp					
water tupelo	1	**25.32**	**34.24**	**29.78**	**25.42**
bald cypress	1	**12.05**	9.38	**10.71**	**9.92**
Ogeechee tupelo	1	8.09	11.14	9.61	8.46
popash	1	5.17	4.79	4.98	2.18
planer tree	1	1.64	1.83	1.73	1.25
swamp tupelo	1	0.69	1.16	0.92	0.50
overcup oak	2	0.54	0.64	0.59	1.45
swamp cottonwood	1	0.12	0.61	0.37	0.31
American elm	2	0.27	0.16	0.22	0.14
red maple	2	0.09	0.28	0.19	0.59
water hickory	2	0.22	0.12	0.17	0.54
green ash	2		0.24	0.12	0.44
river birch	2	0.01	0.19	0.10	0.33
swamp laurel oak	2	0.20		0.10	0.59
sycamore	3	0.02	0.11	0.07	0.02
black willow	1	0.12		0.06	
hackberry	3	0.02	0.05	0.04	0.07
water locust	2	0.02	0.04	0.03	0.31
swamp privet	2	0.02	0.03	0.03	0.004
buttonbush	1	0.02	0.003	0.01	0.01
slippery elm	4	0.02		0.01	
green haw	2		0.01	0.005	0.004
white titi	3		0.004	0.002	
winged elm	4		0.002	0.001	
sweetgum	3				0.05
possum haw	3				0.02
persimmon	3				0.01
ironwood	3				0.004
hazel alder	2				0.002
box elder	3				0.001
Average total basal area, in m²/ha		54.7	65.0	59.8	52.6
Number of trees sampled		640	544	1,184	1,582
Total area sampled, in ha		na	0.72	na	2.45
Number of species		20	21	24	26

Table 8. Density of tree species in forests of the Apalachicola River floodplain, Florida.

[Density, in trees per hectare (trees/ha), was weighted by the percent of area of each forest type in each reach. The sum of the trees/ha of the most dominant species (in **bold**) is greater than 50 percent of the total trees/ha. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Density, in trees/ha				
		Canopy trees				Subcanopy trees
		1976 data			2004 data	2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data		
A. High bottomland hardwoods						
ironwood	3	**176.15**	33.07	**157.28**	**68.80**	34.39
sweetgum	3	**120.35**	**198.50**	**141.80**	**111.90**	22.90
possum haw	3	**104.71**	**51.09**	**109.35**	24.24	**137.27**
hackberry	3	77.51	41.24	73.82	**73.78**	**89.61**
swamp privet	2	40.96	4.94	42.01		
box elder	3	23.20	29.14	27.28	47.67	23.36
swamp laurel oak	2	22.34	18.75	24.52	11.12	6.72
water oak	3	26.09	15.06	23.67	**50.16**	28.87
green ash	2	9.17	**43.46**	18.00	11.41	4.91
overcup oak	2	15.73	5.92	16.76	4.41	9.93
American elm	2	8.67	7.39	9.24	18.29	3.46
Chinaberry	4	5.74	29.64	9.14	8.77	3.15
water hickory	2	6.66	20.74	8.87	12.12	5.12
sycamore	3	11.66	12.10	8.86	9.23	
red maple	2	9.34	4.94	8.43	4.59	4.35
green haw	2	5.20	11.36	5.00	1.77	4.91
swamp chestnut oak	3	5.12		4.69	5.14	4.91
red mulberry	3	4.47	1.48	2.55	3.69	1.45
winged elm	4	2.80	5.18	2.50	18.66	12.56
slippery elm	4	4.43		2.22	3.19	0.57
persimmon	3		5.68	1.20	6.74	11.84
swamp tupelo	1	2.12		1.06	6.59	
black walnut	4		4.94	1.04		
buckthorn bumelia	3	2.1		1.03	2.39	2.84
bald cypress	1	1.4		0.68		
black tupelo	4	0.5		0.25		
spruce pine	3	0.5		0.24		
pagoda oak	3	0.4		0.22		
river birch	2		0.74	0.16	3.64	
loblolly pine	4	0.2		0.10		
American holly	3				38.44	**40.07**
silverbell	4				9.41	5.12
bitternut hickory	3				2.39	7.96
Southern magnolia	4				1.45	
popash	1				0.80	
planer tree	1				0.80	
Chinese tallow tree	3				0.80	
cherry laurel	4				0.80	1.14
Ogeechee tupelo	1				0.73	
elderberry	3					0.60
Average total density, in trees/ha		687	545	702	564	467
Number of trees sampled		352	283	635	671	620
Total area sampled, in ha		na	0.49	na	1.22	1.22

Table 8. (Continued) Density of tree species in forests of the Apalachicola River floodplain, Florida.

[Density, in trees per hectare (trees/ha), was weighted by the percent of area of each forest type in each reach. The sum of the trees/ha of the most dominant species (in **bold**) is greater than 50 percent of the total trees/ha. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Density, in trees/ha				
		Canopy trees				Subcanopy trees
		1976 data			2004 data	2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data		
B. Low bottomland hardwoods						
swamp laurel oak	2	20.25	**74.57**	**47.41**	**35.65**	13.29
overcup oak	2	**56.42**	**32.30**	**44.36**	28.21	26.99
water hickory	2	28.96	**56.57**	**42.77**	**73.87**	19.46
ironwood	3	**40.23**	**44.05**	**42.14**	**35.21**	15.31
green ash	2	**50.82**	31.30	**41.06**	28.90	9.05
river birch	2	**68.07**	9.98	**39.03**	23.81	0.43
American elm	2	**42.41**	**34.34**	38.38	29.67	6.83
red maple	2	39.38	19.22	29.30	**42.16**	**37.68**
sweetgum	3	28.92	19.97	24.44	**35.63**	10.74
planer tree	1	6.18	36.95	21.57	18.71	16.44
possum haw	3	9.00	31.59	20.29	**39.23**	**179.41**
hackberry	3	14.04	16.63	15.33	**38.45**	32.47
bald cypress	1	1.88	24.80	13.34	12.05	2.64
Ogeechee tupelo	1	8.01	18.23	13.12	18.20	4.24
popash	1	6.41	7.43	6.92	8.24	4.87
water tupelo	1	8.30	4.52	6.41	13.08	0.96
green haw	2	5.25	6.88	6.07	3.91	7.70
swamp privet	2	7.87	2.81	5.34	3.25	9.29
sycamore	3	1.70	7.05	4.37	3.85	
black willow	1		8.12	4.06		
box elder	3	7.32	0.53	3.92	9.03	18.33
water locust	2	1.28	6.33	3.81	6.70	1.16
water oak	3	2.73	1.21	1.97	2.58	1.29
swamp cottonwood	1	1.71		0.86	1.79	
laurel oak	4	0.09	1.21	0.65		
persimmon	3	0.68	0.26	0.47	4.49	1.84
black tupelo	4	0.32		0.16		
swamp tupelo	1	0.22		0.11		
swamp chestnut oak	3	0.21		0.11		
buttonbush	1		0.08	0.04	7.44	2.28
stiffcornel dogwood	2				1.73	5.36
red mulberry	3				1.33	
sweetbay	3				0.43	
American holly	3					0.73
Average total density, in trees/ha		459	497	478	528	420
Number of trees sampled		409	602	1,011	1,319	1,240
Total area sampled, in ha		na	1.31	na	2.55	2.55

Table 8. (Continued) Density of tree species in forests of the Apalachicola River floodplain, Florida.

[Density, in trees per hectare (trees/ha), was weighted by the percent of area of each forest type in each reach. The sum of the trees/ha of the most dominant species (in **bold**) is greater than 50 percent of the total trees/ha. Species are sorted by dominance in combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable]

Species	Floodplain species category	Density, in trees/ha				
		Canopy trees				Subcanopy trees
		1976 data			2004 data	2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data		
C. Swamp						
popash	1	**317.03**	**338.25**	**327.64**	**112.31**	**46.81**
water tupelo	1	**308.43**	**292.39**	**300.41**	**224.67**	11.17
Ogeechee tupelo	1	166.87	103.68	135.27	73.24	5.94
bald cypress	1	138.87	115.48	127.17	109.53	**50.01**
planer tree	1	110.15	98.49	104.32	54.18	**55.69**
swamp tupelo	1	6.09	13.41	9.75	6.02	
red maple	2	3.35	10.44	6.90	20.71	19.65
river birch	2	4.48	7.90	6.19	13.73	5.65
swamp cottonwood	1	4.92	6.92	5.92	3.47	0.38
overcup oak	2	3.81	5.67	4.74	17.54	12.50
American elm	2	5.12	3.18	4.15	3.09	4.82
water hickory	2	1.42	4.59	3.00	4.59	7.63
sycamore	3	0.35	5.57	2.96	0.23	
swamp privet	2	2.43	2.19	2.31	0.50	1.08
water locust	2	3.73	0.84	2.29	4.61	1.65
green ash	2		2.07	1.03	6.24	1.50
buttonbush	1	1.54	0.34	0.94	1.08	11.79
hackberry	3	0.39	1.38	0.88	0.69	1.55
black willow	1	1.60		0.80		
green haw	2		1.38	0.69	0.22	0.83
white titi	3		0.84	0.42		0.83
winged elm	4		0.50	0.25		0.19
slippery elm	4	0.48		0.24		
swamp laurel oak	2	0.44		0.22	6.95	3.25
sweetgum	3				2.26	0.40
possum haw	3				2.21	5.45
persimmon	3				1.08	1.08
hazel alder	2				0.46	13.34
ironwood	3				0.46	0.63
box elder	3				0.06	1.84
American snowbell	2					15.35
stiffcornel dogwood	2					4.30
winterberry	2					0.42
sarvis holly	1					0.21
Average total density, in trees/ha		1,082	1,016	1,049	670	286
Number of trees sampled		640	544	1,184	1,582	651
Total area sampled, in ha		na	0.72	na	2.45	2.45

Table 9. Dominant tree species in 1976 and 2004 forests of the Apalachicola River floodplain, Florida.

[The sum of the basal area or density of the dominant species is greater than 50 percent of basal area or density in the data set. Species are listed in each category by descending dominance. Scientific names of species are listed in appendix 1. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods]

Forest type	Type of dominance			
	Basal area		Density	
	1976 data	2004 data	1976 data	2004 data
Hiblh	sweetgum hackberry	sweetgum hackberry water oak	ironwood sweetgum possum haw	sweetgum hackberry ironwood water oak
Loblh	water hickory overcup oak swamp laurel oak green ash	water hickory overcup oak swamp laurel oak green ash	swamp laurel oak overcup oak water hickory ironwood green ash river birch	water hickory red maple possum haw hackberry swamp laurel oak sweetgum ironwood
Swamp	water tupelo bald cypress	water tupelo bald cypress	popash water tupelo	water tupelo popash

Trees Species Abundance throughout the Nontidal Floodplain

Estimates of total basal area and number of trees throughout the entire nontidal floodplain forest are listed in table 10 for 15 tree species individually and for all other species combined. The 15 species include all 14 dominants from table 9 plus Ogeechee tupelo. Ogeechee tupelo had the third highest weighted basal area of any species in any forest type (table 7), but was not a "dominant" species in swamps, because water tupelo and bald cypress had higher basal areas that made up more than 50 percent of total basal area in swamps. Ogeechee tupelo is the source of a unique honey and the high concentration of Ogeechee tupelo in the lower Apalachicola River floodplain makes production of this honey economically feasible (Oertel, 1934; Rahmlow, 1960). Water tupelo was the most important tree in the 1976 and 2004 floodplain in terms of both basal area and number of trees (table 10). Species in table 10 are arranged in descending order by the average FI of all the plots where they were sampled in 1976, based on data presented in appendix 8 for 30 species.

The total number of trees throughout the entire nontidal floodplain forest has decreased significantly by 4.3 million trees (1976, mean (x) = 1,550,000 trees, standard deviation (sd) = 1,056,000; 2004, x = 1,251,000 trees, sd = 870,000; $p < 0.030$) (table 10). The greater part of this loss was in FSC1 species (popash, Ogeechee tupelo, bald cypress, and water tupelo) which lost nearly 3.3 million trees. Unlike bottomland hardwood species that can grow in some swamp habitats downslope that have become drier, swamp species do not usually grow in ponds, stream bottoms, and riverbeds (which are the primary habitats downslope from swamps) because those habitats are still typically inundated year round and do not support trees of any type. All FSC1 species listed in table 10 decreased in basal area although change in basal area was not significant for all species.

Changes in basal area and number of trees for individual species were also statistically analyzed using unweighted basal areas and densities from the replicate plots. The decrease in basal area of popash was highly significant (1976, x = 3.3 m^2/ha, sd = 7.2; 2004, x = 0.9 m^2/ha, sd = 1.9; $p < 0.002$). Although there was a significant difference ($p < 0.078$) between the 1976 and 2004 basal area of bald cypress, the 2004 average basal area of 6.8 m^2/ha was slightly greater than the 1976 basal area of 5.3 m^2/ha on replicate plots, a result that contradicts the results from the weighted values shown on table 10 that shows a 1.3 percent loss in the basal area of bald cypress in 2004.

Changes in tree density, based on statistical analysis of unweighted data, were significant for one Hiblh and three swamp species. Water oak had a significant increase in density (1976, x = 5.2 trees/ha, sd = 17.1; 2004, x = 8.5 trees/ha, sd = 29.3; $p < 0.087$). Although the computed loss of ironwood trees was very large, the decrease in density of ironwood was not statistically significant when replicate plot data were used ($p = 0.150$). Declines in tree density were significant for the swamp species: popash (1976, x = 120 trees/ha, sd = 308; 2004, x = 39 trees/ha, sd = 79; $p = 0.013$), Ogeechee tupelo (1976, x = 78 trees/ha, sd = 259; 2004, x = 32 trees/ha, sd = 59; $p = 0.054$), and water tupelo (1976, x = 196 trees/ha, sd = 435; 2004, x = 140 trees/ha, sd = 259; $p = 0.041$). This represents a decline in density of 63 percent for popash, 59 percent for Ogeechee tupelo, and 29 percent for water tupelo. The same three species had smaller percentage declines in numbers of trees in table 10 (38 percent fewer trees for popash, 44 percent for Ogeechee tupelo, and 19 percent for water tupelo). The results in table 10 are probably better estimates of percentage decline than the density calculations made from unweighted

Table 10. Total basal area and number of trees of important species in forests in the nontidal Apalachicola River floodplain, Florida.

[Total basal area and number of trees were weighted by the percent of area of each forest type in each reach before combining values from forest types. Losses in dominance values are shown in gray. Significant differences between 1976 canopy and 2004 canopy were determined using t-test. Probabilities (p) shown with ** are less than 0.05. Average Floodplain Indices (FI) of plots where sampled are from appendix 8. FSC, Floodplain Species Category]

Species [a]	Average FI of 1976 plots where sampled	FSC	Basal area, in thousands of square meters				Number of trees, in thousands			
			1976	2004	Difference	Difference, in percent	1976	2004	Difference	Difference, in percent
water oak	2.730	3	24.7	29.5	4.8	19.4	235	378	143	60.8
sweetgum	2.614	3	102.7	111.1	8.5	8.3	1,487	1,330	-157	-10.5
hackberry	2.547	3	53.1	52.5	-0.6	-1.2	949	1,159	210	22.2
ironwood	2.528	3	31.0	18.5	-12.5	-40.5	2,600	1,000	-1,601	-61.6
possum haw	2.505	3	9.5	5.5	-3.9	-41.6	553	580	27	4.9
green ash	2.281	2	65.0	56.8	-8.2	-12.6	550	501	-48	-8.8
swamp laurel oak	2.249	2	58.1	64.6	6.5	11.1	1,273	1,839	566	44.4
water hickory	2.154	2	86.2	102.6	16.5	19.1	1,054	985	-69	-6.6
red maple	2.061	2	11.9	19.5	7.6	63.9	1,312	849	-463	-35.3
overcup oak	1.980	2	69.4	68.1	-1.3	-1.9	695	357	-339	-48.7
river birch	1.848	2	29.4	25.7	-3.8	-12.8	577	453	-124	-21.5
popash	1.254	1	52.2	23.8	-28.4	-54.5	3,266	2,027	-1,240	-38.0
Ogeechee tupelo	1.226	1	116.4	105.7	-10.7	-9.2	2,335	1,319	-1,015	-43.5
bald cypress	1.190	1	108.8	107.5	-1.3	-1.2	1,421	1,064	-357	-25.1
water tupelo	1.138	1	295.1	261.6	-33.5	-11.4	3,517	2,836	-680	-19.3
All others			120.9	121.0	0.1	0.1	2,976	3,335	359	12.1
	Total for all species		**1,294.6**	**1,293.7**	**-0.9**	**-0.1**	**24,800**	**20,510**	**-4,290 ****	**-17.3 ****

[a] See appendix 1 for scientific names.

data, because the table 10 results were based on a larger number of sampling plots. Table 10 results, however, could not be tested statistically because of weighting calculations needed to estimate numbers of trees floodplain-wide. It can reasonably be assumed that declines in number of trees for these three swamp species are at least 38 percent for popash, 44 percent for Ogeechee tupelo, and 19 percent for water tupelo.

Distribution of Species

Changes in the distribution of all species were examined by comparing 1976-1984 data (including data from Gholson, 1985) to the 2004 data. The plant species lists created by Gholson in 1984 are the most complete listing of species throughout the floodplain. Only species listed by Gholson as occurring in the overstory and understory or as trees and shrubs were compared to 2004 canopy and subcanopy trees.

All 14 dominant species are found throughout the nontidal floodplain from rm 104.8 (the upstream limit of sampling) to rm 19.8 (the downstream limit of the nontidal area). Ogeechee tupelo was not observed on the Apalachicola River floodplain upstream of rm 85.8 in any of the studies. The distribution of these 15 species has not changed since 1976.

Three tree species, with sample sizes of 10 or more in the 2004 data, were not sampled in the 1976 datasets. The most important of these species is American holly. Out of 3,572 canopy trees sampled in the 2004 data, 32 trees were American holly. An additional 40 American holly trees were found in the 2004 subcanopy. In the 1976 data, no American holly trees were sampled in a total of 2,830 canopy trees. In 1984, however, Gholson (1985) recorded American holly in the upper and lower reaches, and the 2004 data showed that it was found in all reaches of the nontidal floodplain. On the Ochlockonee River floodplain, American holly grew on the high terraces at higher median elevations than water oak or sweetgum (Light and others, 1993).

Silverbell is a small canopy tree that was sampled in the upper and middle reaches in Hiblh forests in 2004 (11 canopy trees, 9 subcanopy trees), but was not sampled in 1976. The range of this tree in 1984 in the Gholson study was similar to its range in 2004.

Fifteen American snowbells were found in the 2004 subcanopy on the WEW transect in the middle reach and on plots in the lower reach, but the species was not recorded in the 1976 canopy or subcanopy and was seen by Gholson only in tidal floodplains downstream of rm 19. American snowbell was a subcanopy species found only in the upper tidal reach of the Suwannee River (Light and others, 2002). The change in distribution of American snowbell may be an indicator of decreased flood durations occurring in the lower part of the nontidal floodplain.

Two exotic species that commonly grow on disturbed sites in upland or wetland forests may have increased their range in the Apalachicola River floodplain. Chinaberry was sampled only in the upper reach in the 1976 data and the Gholson study, but was in both the upper and middle reaches in the 2004 data. Although only one canopy specimen of Chinese tallow tree was recorded on 2004 plots, this exotic species was observed growing in the upper and middle reaches at many sites. No Chinese tallow trees were recorded in the 1976 data or by Gholson.

Basal Area and Density of Trees by Forest Type and Floodplain Species Category

Basal area and density of 1976 and 2004 forest types and species grouped by FSCs were calculated from replicate plot data (71 pairs, 142 plots) so that t-tests could be used to determine significance of differences. The total basal area and density of forest types shown in figure 13 are weighted by the percentage of area of the forest type in each reach, but statistical results shown in the figure were calculated using unweighted replicate plot data. Means of the weighted data are slightly different from means of the unweighted data.

Basal area did not change significantly from 1976 to 2004 (fig. 13). The relative stability of average basal area by forest type should not be construed as the overall condition of bottomland hardwood forests in the 2004 floodplain because there was a sampling bias toward undisturbed sites. Many of the 1976 Hiblh and Loblh plots were not sampled in 2004 because of clear-cutting, especially on the CH, OR, and MR transects. Less clear-cutting occurred in swamps than occurred in bottomland hardwoods (although one swamp plot at WEW was cleared). Evidence of selective cutting in swamps was recorded in 1976 as well as in 2004, usually as bald cypress stumps, but was not common in either survey.

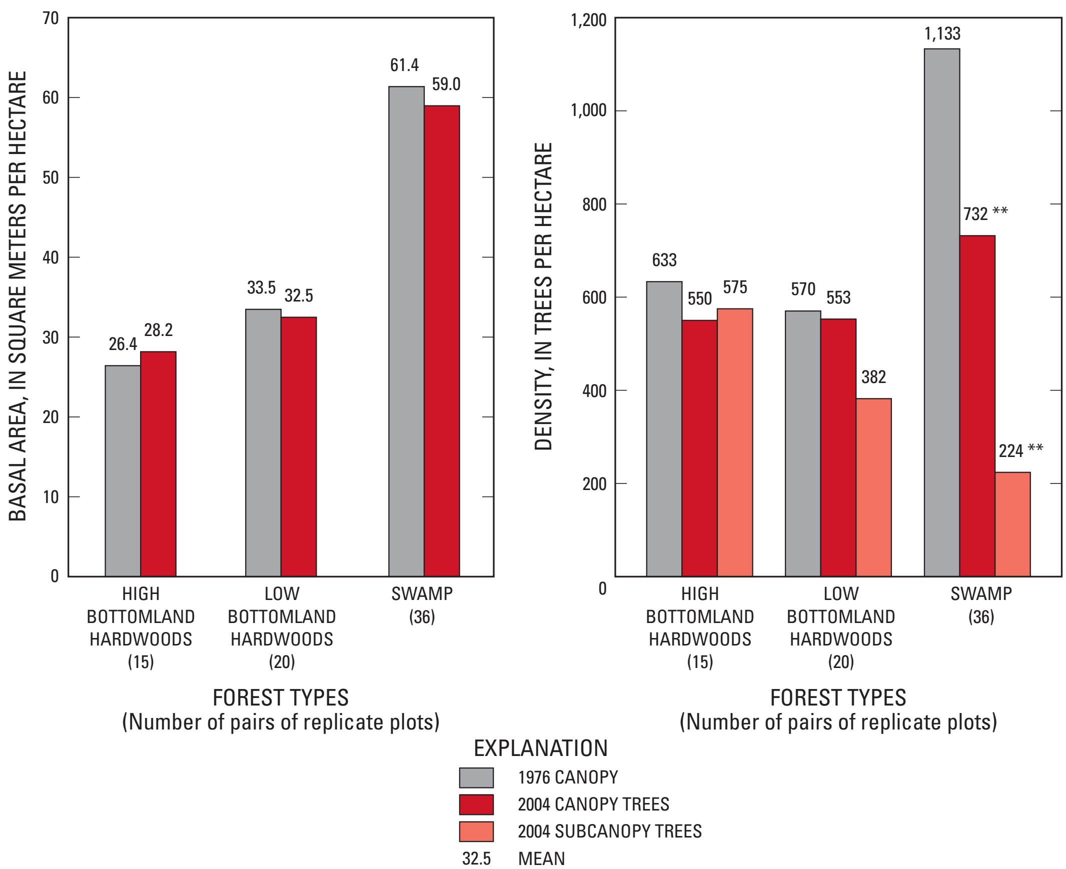


Figure 13. Mean basal area and density of trees on 1976 and 2004 replicated forest plots in the Apalachicola River floodplain, Florida. Number of pairs of replicate plots are given in parentheses below forest types. Basal area and density were weighted by the percent of area of each forest type in each reach. Probabilities (p) determined from t-test are based on unweighted data. P values shown with **, < 0.05.

Canopy density has decreased in all forest types, and the loss of density (37 percent less) was highly significant in swamps (1976, x = 1111 trees/ha, sd = 875; 2004, x = 699 trees/ha, sd = 427; p = 0.001). Subcanopy tree density in 2004 swamps was also significantly less than 1976 canopy density in swamps (1976 canopy, x = 1100 trees/ha, sd = 902; 2004 subcanopy, x = 290 trees/ha, sd = 436; p < 0.001).

The decrease in density of canopy trees in swamps has important ramifications for future swamp composition. Thinning of the canopy allows more sunlight on the forest floor, which may allow greater growth of ground-cover plants on the forest floor. In turn, the thicker ground cover makes it more difficult for tree seedlings to become established. Some swamps that were known to be nearly bare of ground cover in 1976 were densely covered with grasses and sedges in 2004 (cover photo). The average extent of ground cover on 2004 swamp plots averaged nearly 40 percent. In the Suwannee River floodplain, the same observer estimated ground-cover extent to average about 25 percent in nontidal swamps (Darst and others, 2002). Most of the ground cover species seen in 2004 swamps in the Apalachicola River floodplain were perennial sedges, and grasses such as savannah panicum (*Phanopyrum gymnocarpon*).

When species in each forest type were grouped by FSCs, the changes in density from the 1976 canopy to the 2004 canopy and subcanopy on replicated plots was significantly toward drier forest compositions in Loblh forests and swamps (fig. 14). In all forest types, the dominant FSCs in the 1976

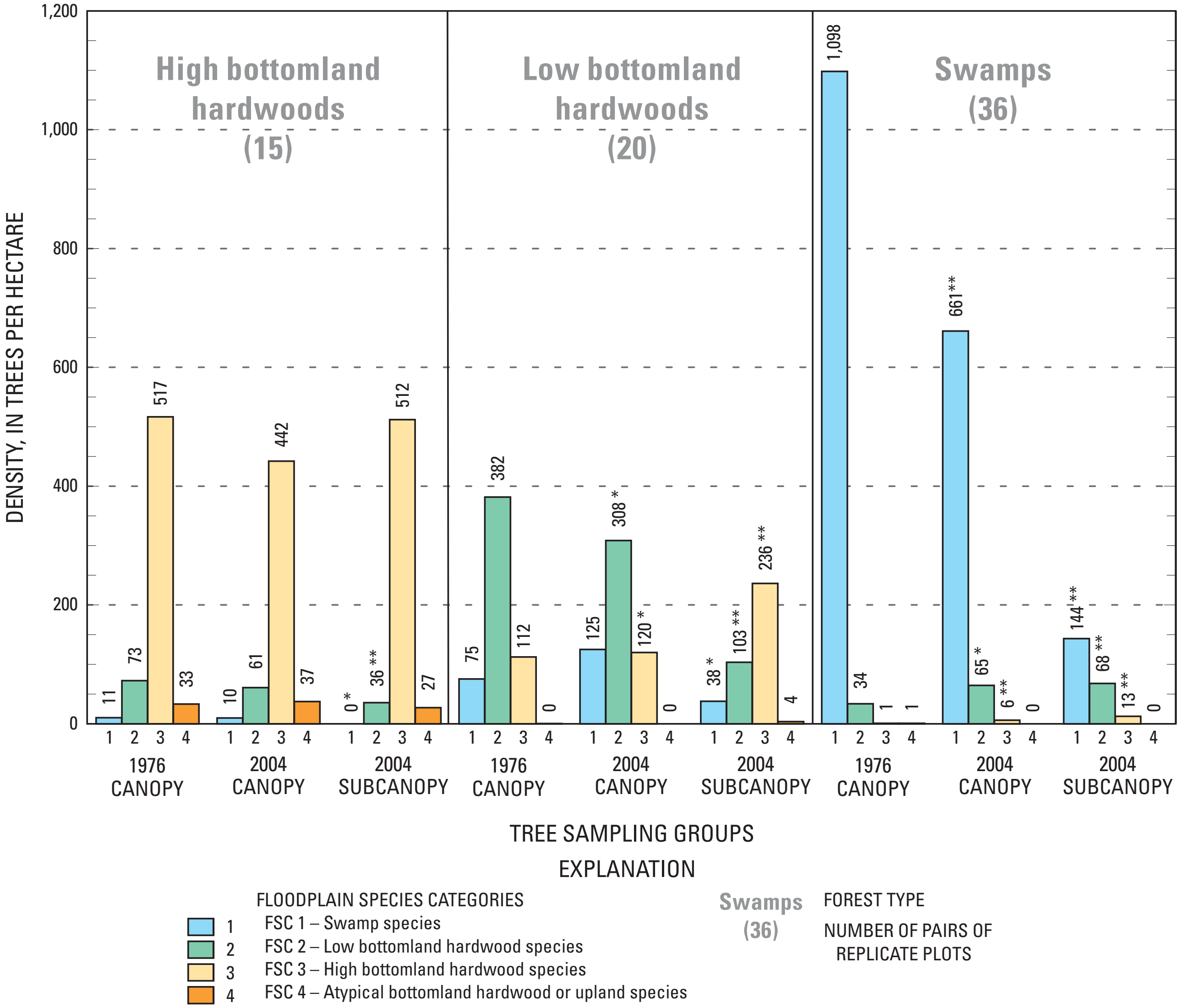


Figure 14. Mean density of trees grouped by Floodplain Species Categories on replicated forest plots (1976 and 2004) in the Apalachicola River floodplain, Florida. Number of pairs of replicate plots are given in parentheses below forest types. Densities were weighted by the percent of area of each forest type in each reach. Significant differences between 1976 canopy and 2004 canopy and subcanopy were determined using t-test. Probabilities (p) were calculated using unweighted data. P values shown with * are < 0.1 but > 0.05; with **, < 0.05.

canopy had a lower density in both the 2004 canopy and subcanopy. For example, in Loblh forests, the density of FSC2 species (green bars) was significantly less in the 2004 canopy and subcanopy than it was in the 1976 canopy. In Loblh forests, the density of the next drier FSC group (FSC3, tan bars) had significantly increased in 2004. In swamps, the FSC2 group increased in density while the FSC1 group decreased. The results of statistical tests on unweighted data from replicate plots are shown in table 11. The mean values for unweighted data are slightly different from values for weighted data.

Table 11. Statistical evaluation of differences between densities of trees grouped by Floodplain Species Categories on replicate forest plots (1976 and 2004) in the Apalachicola River floodplain, Florida.

[Significant differences between 1976 canopy and 2004 canopy and subcanopy density of Floodplain Species Categories (FSC) were determined using t-test. Canopy includes trees ≥ 7.5 centimeter (cm) diameter at breast height (dbh); subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; sd, standard deviation; x, mean; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

(orange)	Indicates difference is highly significant (p ≤ 0.05)
(yellow)	Indicates difference is less significant (p < 0.1 > 0.05)
(gray)	Indicates difference is not significant (p ≥ 0.1)

Forest type (number of pairs of replicate plots sampled)	FSC group	Mean density, in trees/ha, and standard deviation			Statistical significance of difference from 1976 canopy density for:	
		1976 canopy	2004 canopy	2004 subcanopy	2004 canopy	2004 subcanopy
Hiblh (15)	FSC1	x = 4.8 sd = 40.2	x = 8.8 sd = 17.2	x = 0 sd = 0	p = 0.312	p = 0.087
	FSC2	x = 72.4 sd = 72.4	x = 60.3 sd = 47.9	x = 33.4 sd = 26.0	p = 0.287	p = 0.026
	FSC3	x = 459.7 sd = 397.9	x = 433.9 sd = 152.7	x = 581.6 sd = 524.3	p = 0.396	p = 0.265
	FSC4	x = 47.4 sd = 125.6	x = 46.5 sd = 59.9	x = 34.7 sd = 59.3	p = 0.487	p = 0.357
	All	x = 594.3 sd = 412.1	x = 549.4 sd = 153.2	x = 649.7 sd = 524.6	p = 0.326	p = 0.392
Loblh (20)	FSC1	x = 58.7 sd = 85.4	x = 84.0 sd = 135.6	x = 28.6 sd = 39.6	p = 0.166	p = 0.091
	FSC2	x = 360.8 sd = 263.1	x = 248.4 sd = 147.0	x = 99.2 sd = 91.1	p = 0.044	p < 0.001
	FSC3	x = 101.5 sd = 94.7	x = 161.4 sd = 145.4	x = 301.2 sd = 237.6	p = 0.063	p = 0.001
	FSC4	x = 0.33 sd = 1.5	x = 0 sd = 0	x = 2.0 sd = 5.9	p = 0.165	p = 0.135
	All	x = 521.3 sd = 299.5	x = 493.9 sd = 160.5	x = 431.1 sd = 230.3	p = 0.367	p = 0.239
Swamp (36)	FSC1	x = 1,067.6 sd = 884.7	x = 609.8 sd = 461.6	x = 174.2 sd = 405.5	p < 0.001	p < 0.001
	FSC2	x = 39.0 sd = 102.8	x = 75.1 sd = 107.6	x = 90.8 sd = 148.1	p = 0.084	p = 0.009
	FSC3	x = 2.6 sd = 9.2	x = 13.8 sd = 32.4	x = 25.1 sd = 56.4	p = 0.016	p = 0.013
	FSC4	x = 1.8 sd = 10.2	x = 0 sd = 0	x = 0.3 sd = 1.9	p = 0.143	p = 0.188
	All	x = 1,111.1 sd = 874.6	x = 698.6 sd = 426.8	x = 290.5 sd = 436.2	p = 0.001	p < 0.001

Growth Rates, Tree Sizes, Mortality, and Recruitment

Data on tree species and forest types were obtained at eight thesis plots in 2004 by sampling the survivors of the trees that were sampled in 1976. Analyses of these data are presented in detail, because information of this type is rarely available for the same set of trees over a long period of time (28 years).

Growth Rates

The average growth rate for all tree species on the thesis transects was 0.38 cm/yr (table 4). All results were shown in table 4 regardless of sample size because growth rates of many floodplain tree species are poorly known. Species that are typically dominant in Hiblh forests would be expected to have optimum growth rates in Hiblh forests, but sweetgum and hackberry grew at a faster rate in Loblh than in Hiblh forests (table 4). Drier conditions may have slowed the growth of these species in Hiblh forests relative to their growth in Loblh forests. Slow-growing species, such as green haw, possum haw, persimmon, and box elder are typically small canopy trees at maturity. When young, these smaller trees may grow more rapidly in temporary openings in the canopy and then grow very slowly when ultimately suppressed by the taller canopy trees. Most possum haw and popash trees have multiple trunks, and growth rates for these species may not apply to any individual trunk, but are still indicative of the rate of increase in biomass.

Growth rates of 51 trees at the BLT transect were compared statistically to growth rates for the same trees determined from tree-ring samples taken in 2006 (Smith, 2007). The 51 trees sampled were of 5 species (bald cypress, hackberry, swamp laurel oak, overcup oak, and green ash) and had an average dbh of 42 cm. No significant difference was found between growth rates of individual trees determined by Smith from tree rings and those calculated from dbh measurements ($p = 0.647$) using the Wilcoxon matched-pairs signed-ranks test.

Incremental Tree-Size Groups

Incremental size groups of trees on the thesis plots in 1976 and 2004 are shown in figure 15. The tops of the bars form the inverted J-shaped curve that is typical of mature, continually regenerating forest stands (Shimano, 2000). The slightly less steeply curved shape of the 2004 data size groups indicates some maturing of the forests with an increase in the number of trees in the number 5 or larger size groups.

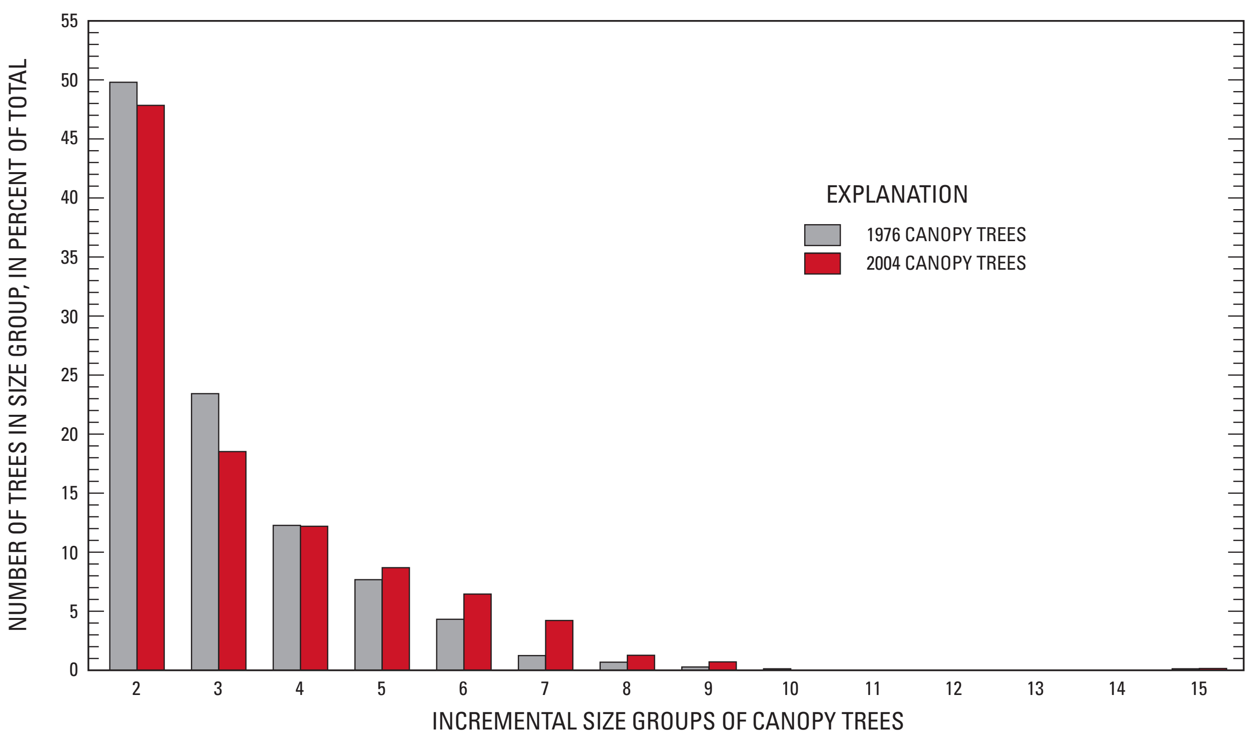


Figure 15. Incremental size groups of canopy trees on the thesis transects in 1976 and 2004 on the Apalachicola River floodplain, Florida. Incremental size groups of canopy trees have diameters at breast height in 10 cm increments beginning with size group 2 (≥ 7.5 and < 17.4 cm) and ending with size group 15 (≥ 137.5 and < 147.4 cm).

Changes in incremental tree-size groups (fig. 15), total basal area, and average dbh of canopy trees (table 12) for forest types support the conclusion that, although the forests at the thesis transects appeared to be mature in 1976, some additional maturation had occurred by 2004. At the WEW transect, the position of the site on newly created land formed by a laterally accreting bank (fig. 5) helps explain why forests were younger at the WEW transect in 1976, but the BLT transect is on an eroding channel bank. Forests on the BLT transect appeared to be mature in 1941 aerial photos (fig. 3), but they may still have been recovering from selective cutting done in the late 1800s and early 1900s, because the maximum potential for biomass had not been realized in 1976.

Mortality and Recruitment Rates

Out of 717 canopy trees surveyed at BLT and WEW in 1976, 255 trees were dead in 2004 (table 12). Snags, stumps, holes, or depressions were evident where most trees had died. The combined mortality rate averaged 1.3 percent per year at both transects. By 2004, 251 new canopy trees appeared at both transects, bringing back the total number of canopy trees alive in 2004 to 713. Tree numbers were maintained in a nearly steady state by mortality and recruitment rates, but there was a small net loss of trees at BLT (2.2 percent) and an increase in trees at WEW (4.7 percent) over an average of 28 years.

Mortality per year at both transects was lower in swamps and in Loblh plots than in the only Hiblh plot (the levee at BLT), which had a mortality rate of 1.5 percent. Average recruitment rates per year were highest in Loblh and lowest in Hiblh. The net result of these changes is a loss of tree density in Hiblh and in swamps, and a gain in tree density in Loblh forests.

Mortality and recruitment of 14 tree species at the thesis transects are shown in table 13. Although water oak is a dominant species (table 9), it was not included, because only one tree was sampled on the thesis plots in 1976. Four species dominant in Hiblh forests (sweetgum, hackberry, ironwood, and possum haw) had higher recruitment in Loblh than in Hiblh forests, which could be an indication of drier hydrologic conditions. Although all three species, which are listed as intolerant of shade, are in decline at the thesis transects (which might be expected in maturing forests), several species listed as intermediate or very tolerant of shade are also decreasing in density.

Table 12. Composition characteristics of 1976 and 2004 forest types at the BLT and WEW transects in the Apalachicola River floodplain, Florida.

[Data were collected at plots used in thesis research by Leitman (1978). Data from 1976 were modified to match boundaries of remnant plots in 2004. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; dbh, diameter at breast height; ha, hectare; m^2, square meters]

	Forest Types							
	Hiblh		Loblh		Swamp		All types	
	1976	2004	1976	2004	1976	2004	1976	2004
Area, in ha	0.266	0.266	1.012	1.012	0.322	0.322	1.6	1.6
Total basal area, in m^2	8.98	9.79	22.72	31.05	8.21	11.37	39.91	52.21
Basal area, in m^2/ha	33.7	36.8	20.6	27.7	28.9	37.7	24.9	32.6
Average dbh per canopy tree, in centimeters	22.0	26.9	22.2	23.6	23.0	28.0	22.3	24.9
Number of trees	168	123	430	479	119	111	717	713
Density, in trees/ha	632	462	398	448	385	369	488	446
Dead trees in 2004	70		149		36		255	
Mortality, in percent of trees per year	1.5		1.2		1.1		1.3	
New trees in 2004	25		198		28		251	
Recruitment, in percent of trees per year	0.5		1.7		0.8		1.3	
Net change in density, in percent of trees per year	-1.0		0.5		-0.3		0.0	

Floodplain Indices

FIs were used to quantitatively compare the relative wetness or dryness of forest tree species compositions. The FIs of plots and tree-size classes in 1976 and 2004 forests were compared to each other and to FIs from forests on other north Florida streams. The changes in FIs at the thesis plots, where 1976 trees were exactly recovered in 2004, are also discussed. The significance of differences in FIs was statistically examined with the Wilcoxon matched-pairs signed-ranks test.

Replicate Plots

The composition of 2004 plots that replicated 1976 plots (71 pairs of plots) averaged 4.4 percent (+0.044) drier ($p = 0.086$, table 14, app. 9). Analysis of replicate plots grouped by forest types indicates that most of this drying occurred in swamps that were significantly drier in 2004 (8.8 percent, $p = 0.026$). Analysis grouped by reach indicated that replicate plots of all forest types in the upper reach averaged 5.0 percent drier in composition than in 1976 forests ($p = 0.066$). Replicate plots in the middle and lower reaches were not significantly drier in composition than 1976 plots.

The relatively small change in FIs of 4.4 percent found in replicate plot sampling was probably due to the importance of the large canopy trees in determining FIs. The total basal area of the large canopy trees was more than 80 percent of the total basal area for all trees in the 1976 and 2004 datasets. The 2004 large canopy tree-size class, with a median age of 99 years (table 5), grew in pre-1954 hydrologic conditions for nearly half of their lives. Eventually, the larger trees will be replaced by trees that have lived entirely in post-1954 years.

A comparison of FI values for the 1976 canopy and small canopy tree classes on the eight exactly replicated thesis plots is shown in table 15. The 1976 small canopy trees were drier at five plots and wetter at three plots than the 1976 canopy tree-size class. If the smaller canopy tree-size class was an indicator of the future composition of the canopy, five plots would be expected to have become drier and three would have become wetter. The 1976 small canopy composition predicted the direction of change (to drier or wetter FI) in composition of the 2004 canopy correctly in seven of eight cases. At one Loblh plot at WEW, the canopy became drier despite the indication of a future change to a wetter canopy.

Table 13. Mortality and recruitment of 14 tree species on the BLT and WEW transects in the Apalachicola River floodplain, Florida.

[Species are listed in descending order by net change. Scientific names of species are listed in appendix 1. FSC, floodplain species category; Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; yr, year]

Species	FSC	Sample size	Shade tolerance[a]	Mortality, in percent/yr				Recruitment, in percent/yr				Net change, in percent/yr
				Hiblh	Loblh	Swamp	All	Hiblh	Loblh	Swamp	All	
Ogeechee tupelo	1	17	not listed		0.000	0.000	**0.000**		7.181	4.695	**5.280**	**5.28**
hackberry	3	46	very tolerant	0.399	0.873		**0.781**	0.000	2.135	new	**2.030**	**1.25**
ironwood	3	36	very tolerant	1.056	1.134		**1.097**	1.690	2.835		**2.294**	**1.20**
overcup oak	2	46	moderately intolerant	1.795	0.850	1.795	**1.015**	0.598	1.795	1.795	**1.639**	**0.62**
swamp laurel oak	2	52	intermediate to intolerant	1.306	1.051		**1.105**	0.326	2.102		**1.726**	**0.62**
red maple	2	22	tolerant		1.026	0.449	**0.816**	new	1.795		**1.306**	**0.49**
bald cypress	1	23	intermediate		0.000	0.239	**0.156**		1.795	0.000	**0.624**	**0.47**
possum haw	3	36	very tolerant	1.867	0.979		**1.596**	0.575	3.591		**1.496**	**-0.10**
green ash	2	45	intermediate	1.436	1.197	1.795	**1.277**	0.000	1.415	0.000	**1.037**	**-0.24**
water hickory	2	65	intermediate	3.591	1.274		**1.381**	1.197	0.985		**0.994**	**-0.39**
water tupelo	1	17	intolerant			0.785	**0.785**			0.000	**0.000**	**-0.79**
sweetgum	3	116	intolerant	1.323	1.643		**1.486**	0.063	0.669		**0.371**	**-1.11**
popash	1	36	intermediate		1.197	2.067	**1.995**		0.000	0.000	**0.000**	**-2.00**
river birch	2	7	intolerant	3.591	2.394		**2.565**	0.000	0.000		**0.000**	**-2.57**

[a] From Clark and Benforado, 1981.

Table 14. Changes in Floodplain Indices from 1976 to 2004 for replicate plots grouped by reach and forest type in the Apalachicola River floodplain, Florida.

[Results are listed for individual plots in appendix 9. A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. FIs are calculated from relative basal areas of canopy trees weighted by the Floodplain Species Category. Significant differences between 1976 canopy and 2004 canopy were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; n; sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for 2004 plot is drier than FI for 1976 plot (difference is positive)
Indicates FI for 2004 plot is wetter than FI for 1976 plot (difference is negative)

Reach	Forest type	Sample size	Average Floodplain Indices (FI)		Difference in FI (2004 canopy minus 1976 canopy)
			1976 canopy	2004 canopy	
UPPER	Hiblh	9	2.801	2.821	0.019
	Loblh	7	2.150	2.183	0.033
	Swamp	14	1.034	1.113	0.079 *
	All	30			0.050 *
MIDDLE	Hiblh	6	2.804	2.799	-0.005
	Loblh	11	1.997	2.018	0.021
	Swamp	16	1.138	1.256	0.118
	All	33			0.063
LOWER	Loblh	2	1.995	1.666	-0.328
	Swamp	6	1.015	1.044	0.029
	All	8			-0.061
		Average difference in FI for Hiblh (n = 15)			**0.010**
		Average difference in FI for Loblh (n = 20)			**-0.010**
		Average difference in FI for Swamp (n = 36)			**0.088 ****
		Average difference in FI for all plots (n = 71)			**0.044 ***

The Hiblh plot at BLT had the greatest change to drier composition of any thesis plot (18 percent, table 15). This plot was located on an eroding bank and part of the original plot was gone in 2004. Increased drainage caused by close proximity of this plot to the river channel probably contributed to the change to drier species composition. The Loblh plot adjacent to the Hiblh plot at BLT was not in close enough proximity to the channel to be affected by increased drainage. That Loblh plot and the swamp plot on the BLT transect were wetter in composition in 2004 than in 1976. The swamp plot is in a depression that collects water during heavy rains and retains water after river overflows. The Loblh plot is connected to the same swamp by a shallow swale. If beaver activity (which was observed in the BLT swamp in 2005) is greater now than it was prior to 1976, water retention on these two plots could have increased.

Floodplain forests could change to a drier species composition if flood durations become shorter or if the deposition of alluvial sediments increased ground elevations. There was no evidence of significant sedimentation on either thesis transect since 1976. Photographs taken from about the same spot in 1977 and 2005 at the BLT transect show a remarkable similarity in the exposure of tree bases (fig. 16).

FIs of canopy trees on all thesis plots averaged 6.7 percent drier from 1976 to 2004 (table 15), which was more than the average difference for the whole replicate plot set (4.4 percent, table 14). The rate of change in FI values from 1976 to 2004 for canopy trees at all thesis plots averaged 0.2 percent drier per year. If this rate of change remains constant, plots at the WEW and BLT transects could become 19.4 percent drier than the 2004 canopy by 2085, the year when the median age of surviving 2004 subcanopy trees will reach the median age (99 years) of the 2004 large canopy trees.

1976 Size Classes

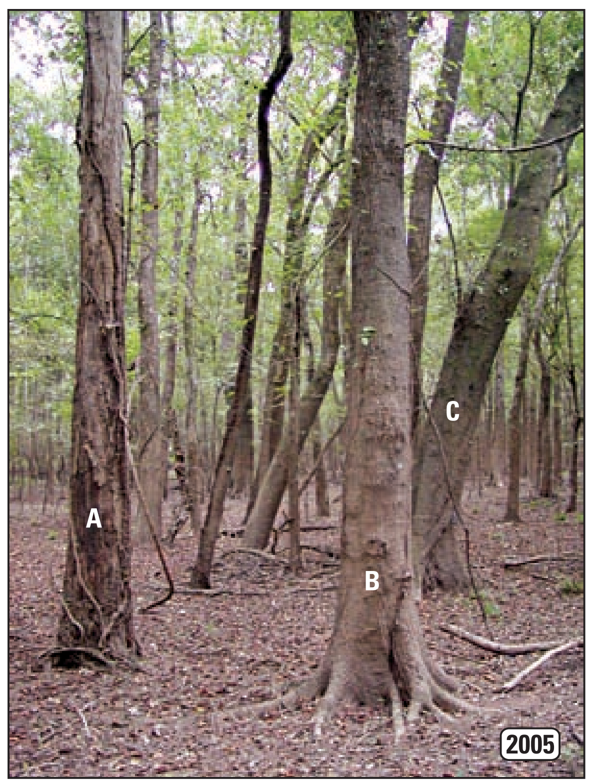
Water-level decline began in 1954, so FI values for the tree-size classes at the 1976 thesis and ARQA intensive plots were analyzed to determine if changes to drier forest composition were already evident in 1976. At these 21 plots, the average FI value for all canopy trees was significantly

Table 15. Change to drier or wetter species composition of the 2004 canopy predicted by differences in Floodplain Indices between the 1976 canopy and 1976 small canopy tree-size classes at plots on the BLT and WEW transects in the Apalachicola River floodplain, Florida.

[Plots located at the BLT and WEW transects were sampled in 1976-1977 (Leitman, 1978) and resampled in 2004-06. The elapsed years between surveys was 28.2 years at the WEW transect and 27.5 years at the BLT transect. A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition, as determined by dominance, toward a drier forest type. FIs are calculated from relative basal areas. Canopy trees are ≥ 7.5 centimeter (cm) diameter at breast height (dbh); small canopy trees are < 25 and ≥ 7.5 cm dbh; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI is drier than FI of 1976 canopy (difference is positive)
Indicates FI is wetter than FI of 1976 canopy (difference is negative)

Transect	Forest type of plot	Floodplain Index (FI)			Difference in FI		Was the direction of change in FI for the 2004 canopy predicted correctly by the FI of the 1976 small canopy?	Annual rate of positive change in FI (to drier species composition)
		FI for 1976 canopy	1976 small canopy trees	2004 canopy trees	1976 small canopy minus 1976 canopy	2004 canopy minus 1976 canopy		
WEW	Loblh	1.767	1.820	1.933	0.053	0.166	yes	0.006
	Loblh	1.914	1.587	2.062	-0.327	0.148	no	0.005
	Swamp	1.134	1.208	1.224	0.074	0.090	yes	0.003
BLT	Hiblh	2.650	2.772	2.830	0.122	0.180	yes	0.007
	Loblh	2.228	2.103	2.092	-0.125	-0.136	yes	-0.005
	Loblh	2.335	2.640	2.435	0.305	0.100	yes	0.004
	Loblh	2.128	2.279	2.146	0.151	0.018	yes	0.001
	Swamp	1.077	1.042	1.048	-0.035	-0.029	yes	-0.001
	Average	**1.904**	**1.931**	**1.971**	**0.027**	**0.067**		0.002



Photographs by Helen Light

Figure 16. Low bottomland hardwood forest on the BLT transect in 1976 and 2005 in the upper reach of the Apalachicola River floodplain, Florida. Although lens distortion varies between these two photographs taken 29 years apart, they were taken from the same location facing in the same direction. Three trees that were present in 1976 and 2005 are marked A, B, and C. Surviving tree bases are exposed to the same extent in both photographs, indicating that no significant erosion or sedimentation took place between 1976 and 2005.

drier (2.8 percent, p = 0.026) than the FI value for the large canopy tree-size class (table 16), indicating that forest composition had become drier when sampled in 1976 than the forest composition prior to 1954. The 1976 small canopy tree size was 8.8 percent drier than the 1976 canopy (p = 0.080), indicating that forests would probably become drier on these plots in the future.

The upper reach had the largest sample size (n = 12) of any reach or forest type, and the average differences in FI values for size classes were significant only for this subset. Forests in the upper reach were 4.0 percent drier in composition than they were prior to 1954 (p = 0.032) (using the large canopy tree-size class to represent the pre-1954 forest composition). The average difference in FIs between the small canopy tree-size class and canopy trees in the upper reach was 13.6 percent drier (p = 0.032). Forest drying may have proceeded more quickly in the upper reach than in downstream reaches, because large declines in water levels in the upper reach occurred rapidly in the first 10 years after the dam was constructed in 1954 (Light and others, 2006).

2004 Size Classes

Small canopy trees on 2004 forest plots averaged 10.5 percent drier, and subcanopy trees were 31.0 percent drier than canopy trees (table 17, app. 10). Average differences between subcanopy trees and canopy trees were highly significant for all plots combined (p < 0.001), and plots combined by reach or forest type (p ≤ 0.012). The large canopy tree-size class in 2004 forests was 1.6 percent wetter than canopy trees, indicating that the longest time period, including many years prior to 1954, had the wettest hydrologic conditions. The much drier subcanopy tree-size class indicates that the driest conditions occurred in the shortest and most recent time period. The average change for subcanopy trees (31.0 percent drier) is large, indicating a high potential for a much drier canopy in the future.

Size Classes on Other North Florida Streams

Differences in FI values for tree-size classes on the Suwannee, Ochlockonee, Aucilla, St. Marks, and Telogia floodplains suggest that forest composition may be drying on

Table 16. Differences in Floodplain Indices for 1976 canopy tree-size classes in forests of the Apalachicola River floodplain, Florida.

[Data in this table is from thesis plots and Apalachicola River Quality Assessment intensive plots. A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition, as determined by dominance, toward a drier forest type. FIs are calculated from relative basal areas. Tree size class definitions: canopy ≥ 7.5 centimeter (cm) diameter at breast height (dbh); large canopy, ≥ 25 cm dbh; small canopy, < 25 and ≥ 7.5 cm dbh. Significant differences between 1976 canopy and 2004 canopy were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; n, number of plots; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for given size class is drier than FI for canopy trees (difference is positive)

Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

Reach	Forest type	Sample size	Average 1976 Floodplain Indices (FI)			Difference in FI	
			Canopy	Large canopy	Small canopy	Large canopy minus canopy	Small canopy minus canopy
UPPER	Hiblh	4	2.747	2.706	2.895	-0.040	0.148
	Loblh	4	2.194	2.125	2.380	-0.069	0.186
	Swamp	4	1.074	1.063	1.148	-0.011	0.074
	All	12	**2.005**	**1.965**	**2.141**	**-0.040 ****	**0.136 ****
MIDDLE	Loblh	3	1.968	1.977	1.842	0.009	-0.126
	Swamp	2	1.225	1.225	1.233	0.000	0.008
	All	5	**1.693**	**1.671**	**1.749**	**0.006**	**-0.072**
LOWER	Loblh	2	1.995	1.930	2.264	-0.065	0.269
	Swamp	2	1.003	1.000	1.023	-0.003	0.020
	All	4	**1.479**	**1.456**	**1.567**	**-0.034**	**0.145**
			Average difference in FI for Hiblh (n = 4)			**-0.040**	**0.148**
			Average difference in FI for Loblh (n = 9)			**-0.042**	**0.101**
			Average difference in FI for Swamp (n = 8)			**-0.006**	**0.044**
			Average difference in FI for all plots (n = 21)			**-0.028 ****	**0.088 ***

Table 17. Differences in Floodplain Indices between 2004 canopy and subcanopy tree-size classes by reach and forest type in the Apalachicola River floodplain, Florida.

[Results are listed for individual plots in appendix 10. A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward the next drier forest type. FIs for canopy trees are calculated from relative basal areas; for subcanopy trees, from relative density. Canopy trees have diameter at breast height (dbh) ≥ 7.5 centimeter (cm); large canopy trees have dbh ≥ 25 cm; small canopy trees, dbh < 25 and ≥ 7.5 cm; and subcanopy trees, dbh < 7.5 and ≥ 2.5 cm. Significant differences between tree-size classes were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; n = sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for given size class is drier than FI for canopy trees (difference is positive)
Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

Reach	Forest type	Number of plots	Average 2004 Floodplain Indices (FI)				Difference in FI		
			Canopy	Large canopy	Small canopy	Subcanopy	Large canopy minus canopy	Small canopy minus canopy	Subcanopy minus canopy
UPPER	Hiblh	10	2.853	2.820	3.055	3.018	-0.033*	0.202 **	0.165
	Loblh	7	2.183	2.124	2.475	2.702	-0.060**	0.291 **	0.519 **
	Swamp	14	1.113	1.105	1.207	1.533	-0.008**	0.094 **	0.421 **
	All	31	1.916	1.888	2.090	2.276	**-0.028 ****	**0.174 ****	**0.360 ****
MIDDLE	Hiblh	6	2.799	2.785	2.875	2.909	-0.014	0.076	0.109
	Loblh	11	2.018	2.000	2.102	2.474	-0.017	0.085	0.393 **
	Swamp	17	1.241	1.233	1.376	1.398	-0.009	0.135 *	0.171
	All	34	1.767	1.755	1.876	2.059	**-0.012**	**0.108 ***	**0.233 ****
LOWER	Hiblh	3	2.642	2.629	2.647	2.880	-0.013	0.004	0.237
	Loblh	16	2.026	2.006	2.064	2.425	-0.020	0.039	0.399 **
	Swamp	11	1.096	1.093	1.119	1.368	-0.002	0.023	0.274 **
	All	30	1.746	1.734	1.776	2.083	**-0.007**	**0.030**	**0.337 ****
All		95	1.809	1.793	1.914	2.141[a]			
				Average difference in FI for Hiblh (n = 19)			**-0.024 ****	**0.131 ****	**0.159 ****
				Average difference in FI for Loblh (n = 34)			**-0.022 ***	**0.106 ****	**0.423 ****
				Average difference in FI for Swamp (n = 42)			**-0.007 ****	**0.092 ****	**0.289 ****
				Average difference in FI for all plots (n = 95)			**-0.016 ****	**0.105 ****	**0.310 ****

[a]Average difference for subcanopy is based on an average FI of 1.830 for the 2004 canopy of 91 plots. Four plots had no subcanopy trees.

some other north Florida floodplains, but combined results from all five rivers were not statistically significant, and the amount of drying was generally much less than that on the Apalachicola River floodplain (table 18). The average difference between the subcanopy and canopy trees was 11.4 percent drier on the five other floodplains compared with 26.9 percent drier in Apalachicola River floodplains. Values for the Apalachicola River in table 18 differ from those in table 17 because the definition for subcanopy trees is different. Subcanopy trees on the five other floodplains were defined as trees with a dbh < 10.0 cm; therefore, tree data from the Apalachicola River floodplain plots were regrouped for this analysis into size classes with the same definition.

Of the five other streams, the Ochlockonee River is probably the most similar to the Apalachicola River in terms of floodplain characteristics and forest composition. Both are alluvial streams and the Ochlockonee River is geographically closer to the Apalachicola than the other four streams. Unlike the Apalachicola River, however, large canopy trees on Ocklockonee River plots were drier than the canopy trees, and small canopy trees were wetter.

Differences in FI values for size classes on the Suwannee River were the most similar to the differences on the Apalachicola River. The large canopy was 3.5 percent wetter in composition than the canopy, the small canopy trees were 8.8 percent drier than the canopy, and the subcanopy trees were 17.8 percent drier than the entire canopy. This may indicate that water-level decline has occurred on the Suwannee River. Differences in FI values for the large canopy and small canopy size classes on the Suwannee River were statistically significant, but the difference for the subcanopy trees was not significant.

Table 18. Differences in Floodplain Indices of tree-size classes on floodplain forest plots of six North Florida streams.

[Results are based on data from six streams collected from 1987 to 2006. A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. FIs for canopy trees calculated from relative basal areas of trees; for subcanopy trees, from relative density. For this analysis, tree size classes were defined as follows: canopy, diameter at breast height (dbh) ≥ 10.0 centimeter (cm); large canopy trees, dbh ≥ 25 cm; small canopy trees, dbh < 25 and ≥ 10.0 cm; and subcanopy trees, dbh < 10.0 and ≥ 2.5 cm. Significant differences between tree-size classes were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods]

[orange] Indicates FI for given size class is drier than FI for canopy trees (difference is positive)
[blue] Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

River (year sampled)		Difference in FI		
Forest type	Number of plots	Large canopy minus canopy	Small canopy minus canopy	Subcanopy minus canopy
Apalachicola River (2004-06)				
Hiblh	19	-0.007 **	0.120 **	0.190 **
Loblh	34	-0.016	0.081	0.394 **
Swamp	42	-0.005 *	0.083 *	0.279 **
Average for all plots		**-0.009 ****	**0.089 ****	**0.269 ****
Suwannee River (1996-99)				
Hiblh	6	-0.029	0.025	0.064
Loblh	5	-0.047	0.172	0.267
Swamp	5	-0.034	0.108	0.266
Average for all plots		**-0.035 ****	**0.088 ****	**0.178**
Ochlockonee River (1987-90)				
Hiblh	3	0.013	-0.133	0.312
Loblh	3	0.047	-0.352	-0.080
Swamp	3	-0.004	0.035	0.012
Average for all plots		**0.019**	**-0.150**	**0.081**
Aucilla River (1987-90)				
Loblh	2	**0.001**	**-0.031**	**-0.284**
St. Marks River (1987-90)				
Loblh	2	**-0.026**	**0.140**	**-0.198**
Telogia Creek (1987-90)				
Swamp	2	**-0.020**	**0.079**	**0.454**
Average difference in FI on Suwannee, Ochlockonee, Aucilla, and St. Marks Rivers and Telogia Creek plots combined		**-0.016**	**0.014**	**0.114**
Average difference in FI on Apalachicola River plots combined		**-0.009 ****	**0.089 ****	**0.269 ****

Drier Forests Associated with Decline in River Levels

Results of forest composition analyses presented thus far suggest that many forest changes are attributable to drier hydrologic conditions in the floodplain. Temporal changes in hydrologic conditions and forest composition are examined in this section.

To link changes in hydrology to changes in vegetation, the correlations between flood durations in the growing season and FIs were analyzed. Flood durations in the growing season and FIs of four tree-size classes were significantly correlated for Hiblh and Loblh forests, all forest types combined in each reach, and all forest types in all reaches combined (table 19). Flood durations in the growing season in swamps were not significantly correlated to FIs. Correlations for all groups were negative; as flood durations increased, FIs decreased. Correlations with other hydrologic parameters were also tested (not shown on table 19) and FIs of swamps were not significantly correlated to flood durations in the whole year, depths, or frequencies. Hydrologic conditions estimated from river stage, without adjustments for local site characteristics, were generally underestimated for depressional swamps in the floodplain and overestimated for swamps at BR. The Pearson r values, significance, and sample sizes for all forest groups are presented in appendix 11.

Temporal changes in hydrologic conditions are compared to temporal changes in forest composition by presenting both in terms of change toward the next drier forest type. Flood durations during hydrologic periods associated with 1976 and 2004 tree-size classes were used to calculate the change in flood duration toward duration of the next drier forest types. Results from FI analyses are summarized to represent past or potential change to drier forest species composition from pre-1954 to 2085, and the impacts of changes in forest composition are discussed.

Table 19. Correlations between Floodplain Indices of 1976 and 2004 tree-size classes and flood durations in forests of the Apalachicola River floodplain, Florida.

[Flood duration is the average number of days of flooding in the growing season. Correlations in swamp forests are low, primarily because flood durations were calculated directly from stage in the adjacent river channel without any adjustments for water retention in depressions or other factors affecting the relation between river stage and floodplain water levels. Correlations were calculated using Pearson correlation coefficients (r). Details of statistical analyses are given in appendix 11. Canopy includes trees ≥ 7.5 cm diameter at breast height (dbh); small canopy trees are < 25 and ≥ 7.5 centimeter (cm) dbh; subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. Floodplain Indices (FI) for canopy trees calculated from relative basal areas; for subcanopy trees, from relative density. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; p, probability; >, greater than; ≥, greater than or equal to; ≤, less than or equal to]

Orange	Indicates correlation is highly significant ($p \leq 0.05$)
Yellow	Indicates correlation is less significant ($p < 0.1$ and > 0.05)
Gray	Indicates correlation is not significant ($p \geq 0.1$)

Forest type	Reach	Pearson r values for correlations between FIs and flood inundation in the growing season			
		1976 canopy trees	2004 canopy trees	2004 small canopy trees	2004 subcanopy trees
Hiblh	All	-0.499	-0.637	-0.628	-0.439
Loblh	All	-0.405	-0.563	-0.511	-0.603
Swamp	All	-0.081	-0.108	-0.158	-0.163
Reaches	UPPER	-0.648	-0.781	-0.731	-0.669
	MIDDLE	-0.702	-0.757	-0.763	-0.649
	LOWER	-0.785	-0.841	-0.841	-0.776
	Average	**-0.680**	**-0.636**	**-0.603**	**-0.566**

Shorter Flood Durations

Flood durations in the growing season for the 1976 canopy (1923-76) and 2004 subcanopy tree-size class (1995-04) are shown for all forest types in all reaches in figure 17. Flood durations during 1995-04 were shorter than flood durations during 1923-76 for all forest types in all reaches; for example, in Loblh in the middle reach, the median flood duration of 47 days for the 1976 canopy decreased to 27 days for 2004 subcanopy trees.

Change in flood duration toward duration of the next drier forest type was calculated for each forest type in each reach (table 20). The following example is provided to demonstrate how these data were calculated (see formula in section titled “Flood Duration, Depth, and Frequency by Forest Type and Reach”). The change in flood durations for Loblh forest in the middle reach from 1923-76 to 1995-04 was 65.6 percent (last column, table 20). This value was calculated from data in figure 17 as follows:

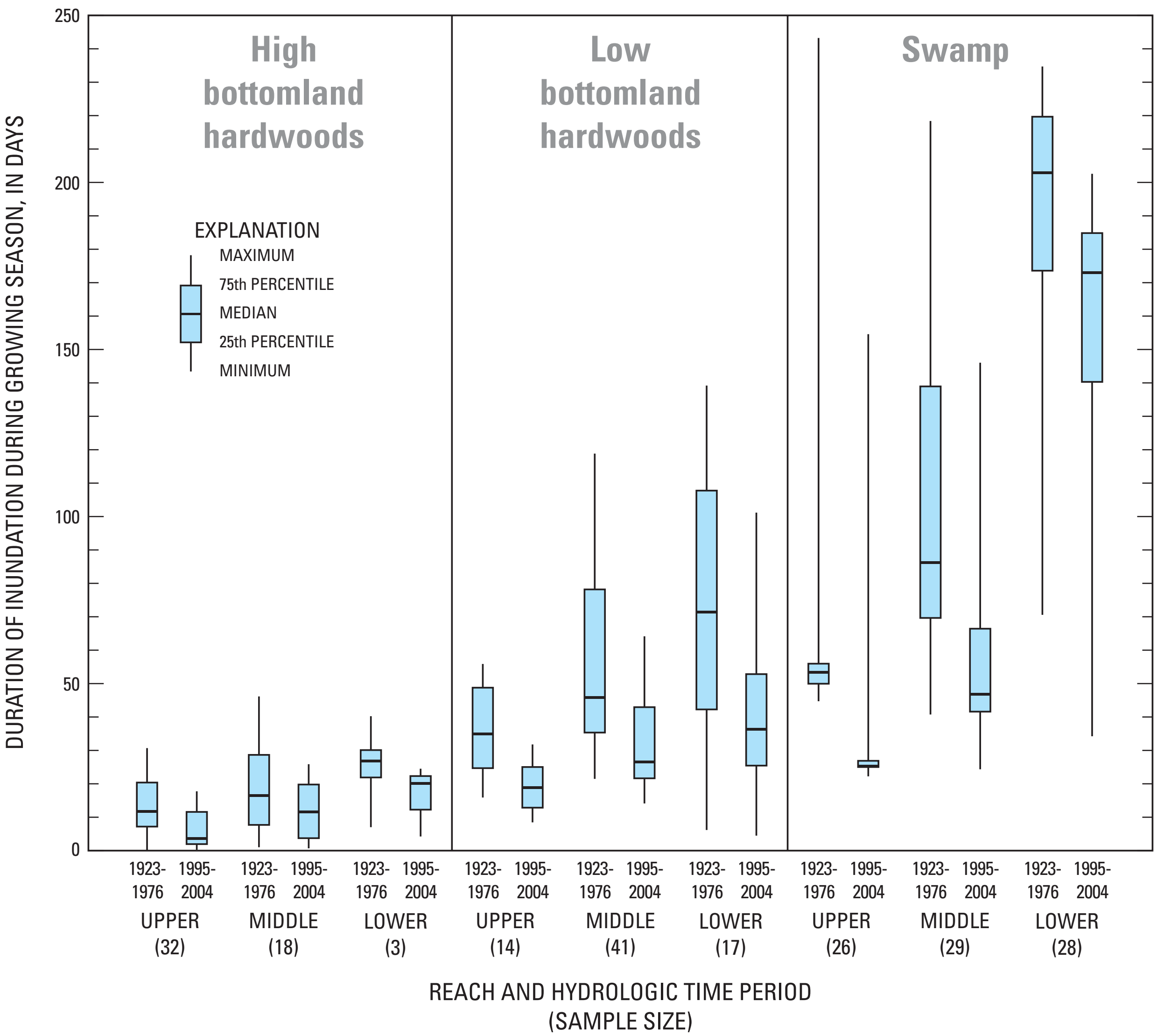


Figure 17. Comparison of earliest (1923-76) and latest (1995-04) flood durations by forest type and reach in the Apalachicola River floodplain, Florida. In most cases, the latest durations are similar to the earliest durations of the next drier forest type, a hydrologic shift that has encouraged a change in forest composition toward a drier mix of species. All values were calculated directly from stage in the adjacent river channel without any adjustments for water retention in depressions or other factors affecting the relation between river stage and floodplain water levels.

Table 20. Changes to shorter flood durations in forests of the Apalachicola River floodplain, Florida.

[Flood duration is the average number of days of flooding in the growing season based on stage in the adjacent river channel without any adjustments for water retention in depressions or other factors affecting the relation between river stage and floodplain water levels. The time period from 1923 to 1976 is associated with 1976 canopy trees; 1951 to 2004, 2004 canopy trees; 1976 to 2004, 2004 small canopy trees; 1995 to 2004, 2004 subcanopy trees. Canopy includes trees ≥ 7.5 centimeter (cm) diameter at breast height (dbh); small canopy trees are < 25 and ≥ 7.5 cm dbh; subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Forest type	Reach	Change in flood duration to duration of the next drier forest type, in percent, for time periods associated with forest sampling groups		
		From 1923-76 to 1951-04	From 1951-04 to 1995-04	Total change from 1923-76 to 1995-04
Hiblh	UPPER	32.3	36.4	**68.7**
	MIDDLE	5.8	23.8	**29.6**
	LOWER	10.0	14.8	**24.8**
	All	24.6	25.4	**50.0**
Loblh	UPPER	40.6	26.7	**67.3**
	MIDDLE	33.8	31.8	**65.6**
	LOWER	41.0	37.4	**78.4**
	All	33.6	21.4	**55.0**
Swamp	UPPER	82.8	68.9	**151.7**
	MIDDLE	52.2	45.3	**97.5**
	LOWER	9.3	13.6	**22.9**
	All	52.7	53.4	**106.1**
Reaches[a]	UPPER	**51.9**	**44.0**	**95.9**
	MIDDLE	**30.6**	**33.6**	**64.2**
	LOWER	**20.1**	**21.9**	**42.0**
	All	**37.0**	**33.4**	**70.4**

[a]Average of forest types.

Step 1

- Median flood duration for Loblh in middle reach in the baseline period (1923-76) = 46.70 days
- Median flood duration for Loblh in middle reach in the most recent period (1995-04) = 27.00 days
- Difference (46.70 – 27.00) = 19.70 days

Step 2

- Median flood duration for Loblh in middle reach in the baseline period (1923-76) = 46.70 days
- Median flood duration for Hiblh (the next drier forest type) in middle reach = 16.69 days
- Difference (46.70 – 16.69) = 30.01 days

Step 3

- 19.70 days / 30.01 days = 0.656
- 0.656 * 100 = 65.6 percent change in flood duration toward duration of next drier forest type

Changes in flood durations toward the durations of the next drier forest type are substantial in all forest types in all reaches with every advancing time period (table 20). Total changes in flood durations toward that of the next drier forest type were greatest in the upper reach (95.9 percent), intermediate in the middle reach (64.2 percent), and least in the lower reach (42.0 percent). The total change in flood durations for all floodplain forests was a 70.4 percent shift toward the baseline flood durations of the next drier forest types.

Flood durations have decreased more in swamps (106.1 percent) than in bottomland hardwood forests (50-55 percent). A value for swamps that exceeds 100 percent indicates that the flood duration of swamps has changed to a duration beyond that of Loblh (the next drier type) toward that of Hiblh forests. For some swamps that are directly connected to the river, such as the swamp at PL transect in figure 11A, a measure of hydrologic change, such as shown in table 20, is an accurate one. For other swamps, duration changes calculated from river stage may or may not be accurate, but field observations at the SE swamp (fig. 11B) suggest that decreases in inundation have been quite large even in swamps that do not have direct connections. Swamp duration changes in table 20 provide a rough estimate of relative change in the absence of long-term, site-specific measurements in swamps.

Drier Forest Composition

The total drying estimates for forest types from pre-1954 composition to the composition of future forests in table 21 were based on a combination of the replicate plot and size-class analyses presented in three previous tables. Forest changes from pre-1954 to 1976 were calculated from the difference in FIs of the 1976 large canopy and 1976 canopy trees (table 16). The 1976 large canopy trees are the most representative group for pre-1954 forest composition. Forest changes from 1976 to 2004 were based on canopy trees in the replicate plot analysis in table 14, and the potential for future drying from 2004 to 2085 was calculated from the difference between 2004 canopy and subcanopy trees in table 17. The future forest canopy composition is estimated for 2085, because in that

Table 21. Change in forest composition from pre-1954 to 2085, calculated from Floodplain Indices of 1976 and 2004 tree-size classes in forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. Canopy includes trees ≥ 7.5 centimeter (cm) diameter at breast height (dbh); large canopy trees are ≥ 25 cm dbh; small canopy trees are < 25 and ≥ 7.5 cm dbh; subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. FIs for canopy trees calculated from relative basal areas; for subcanopy trees, from relative density. Significant differences between tree-size classes were determined using Wilcoxon matched-pairs signed-ranks test. Details of statistical analyses are given in appendix 12. All values shown have a probability (p) < 0.1; with na, p ≥ 0.1 or the sample size ≤ 5. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Forest type	Reach	Change in composition to next drier forest type. in percent, for time periods associated with forest sampling groups			
		Pre-1954 to 1976 (change from 1976 large canopy to 1976 canopy trees)	1976 to 2004 (change from 1976 canopy to 2004 canopy trees)	2004 to 2085[a] (change from 2004 canopy to 2004 subcanopy trees)	Total from pre-1954 to 2085 (change from 1976 large canopy to 2004 subcanopy trees)
Hiblh	UPPER	na	na	na	na
	MIDDLE	na	na	na	na
	LOWER	na	na	na	na
	All	na	na	**15.9**	**15.9**
Loblh	UPPER	na	na	51.9	**51.9**
	MIDDLE	na	na	39.3	**39.3**
	LOWER	na	na	39.9	**39.9**
	All	na	na	**42.3**	**42.3**
Swamp	UPPER	na	7.9	42.1	**50.0**
	MIDDLE	na	na	na	na
	LOWER	na	na	27.3	**27.3**
	All	na	**8.8**	**28.9**	**37.7**
Reaches	UPPER	4.0	5.0	36.0	**45.0**
	MIDDLE	na	na	23.3	**23.3**
	LOWER	na	na	33.7	**33.7**
	All	**2.8**	**4.4**	**31.0**	**38.2**

[a]In 2085, the median age of surviving 2004 subcanopy trees will reach the median age (99 years) of the 2004 large canopy trees.

year surviving 2004 subcanopy trees (with a median age of 18 years) will reach the median age (99 years) of the 2004 large canopy trees. Trees with a median age of 99 years in 2085 will dominate canopy composition by basal area. Assuming that recent hydrologic conditions continue, the 2085 canopy will probably have a FI similar to the 2004 subcanopy. Only changes in FIs that have a statistical significance of $p < 0.100$ were included in table 21. Percent of change, significance values, and sample sizes for all forest groups are given in appendix 12.

For all forest types and reaches combined, drying was significant in every time period (table 21). All forests combined were 2.8 percent drier when sampled in 1976 than they were before 1954. Replicate plots averaged 4.4 percent drier in 2004 than in 1976, resulting in a total difference of 7.2 percent drier from pre-1954 to 2004. The 2004 subcanopy trees in all forests were 31 percent drier than 2004 canopy trees. If the future forest composition becomes similar to that of the 2004 subcanopy, the total change in composition of all forests from pre-1954 to 2085 is estimated to be 38.2 percent drier.

In every time period, FI differences for upper-reach forests were larger than those for all forests, with a total change from pre-1954 to 2085 to 45 percent drier. None of the other subgroups had significant changes in all three time periods, probably because sample sizes in the two earliest periods were small.

Although FI differences in composition for most subgroups are significant only in the last time period (2004-85), many of these changes will probably occur well before 2085. FI changes in the 2004 small canopy in table 17 (not shown in table 21) indicate that there is a highly significant difference (10.5 percent drier) between 2004 small canopy and 2004 canopy for all forests combined, with significant drying in many subgroups. On average, about one-third of the 31 percent total drying expected in the 2004-85 time period (table 21) will probably occur by 2050, the year when the 2004 small canopy trees will reach the age of 99, the median age of large canopy trees.

The overall change to drier hydrologic conditions in table 20 (70.4 percent) is much greater than the overall change to drier forest composition in table 21 (38.2 percent). This may have been caused, in part, by differences in calculation methods. The total change in forest composition was calculated using the composition of the 2004 subcanopy trees which had an estimated median age of 18 years. But the time period for hydrologic analysis for 2004 subcanopy trees was limited to only 10 years (1995-04), because the earliest hydrologic records were limited and all time periods associated with tree-size classes needed to be comparable. Most of the subcanopy trees became established before 1995; therefore, a younger generation of trees exists within the present subcanopy, which is probably drier in composition than the reported results.

Drying is expected to exceed 38 percent in the decades beyond 2085. The shift to drier hydrologic conditions has preceded the shift to drier forest composition. This result is expected, considering that forest change occurs gradually and that the composition of canopy trees may not fully reflect the new hydrologic conditions for many decades. Older, established trees with large root systems are able to survive some change in hydrologic conditions but will eventually be replaced by trees of drier species in the altered hydrologic regime. Overall forest composition could become 70 percent drier by the end of the century, especially if river levels continue to remain as low as they were in the 1995-04 period.

Ecological Effects of Altered Floodplain Forests

Trees are a dominant element in the ecological processes of forests. Changes in tree species composition will alter many complex relations that exist between trees and other forest organisms from large vertebrates to soil microorganisms. The degree to which these changes are occurring in Apalachicola River forests can be debated, because most of these relations are poorly understood in floodplain habitats; however, it can be assumed that the basic principles of food chain dynamics are operating in this relatively mature forest environment. Changes in the timing or quality of mast and fruit production, for example, will have an impact on the organisms that feed on them, such as mammals, birds, and insects. Changes in the timing of leaf-out, fruiting, and leaf-drop of canopy trees will affect insect populations that are dependent upon canopy leaves, with consequences for bird populations that feed on canopy insects. Changes in the leaf litter and soil chemistry around the bases of trees will have consequences for insects and microorganisms in the topsoil and the macroinvertebrates that feed upon them directly or indirectly.

These and other ecological effects are occurring to varying degrees in the Apalachicola River floodplain, because the present forest composition is significantly drier than it was in the past. In Hiblh forests, there has been an increase in species like water oak and American holly that can tolerate some inundation but are also well adapted to upland habitats. In Loblh forests, density changes illustrated in figure 14 indicate that competition between Hiblh and Loblh species is increasing and that some Loblh forests will eventually become Hiblh forests. In swamps, the density of Loblh and Hiblh species has increased significantly (fig. 14), but water tupelo, Ogeechee tupelo, bald cypress, popash, and other swamp species have declined to such an extent that the overall density of canopy trees in swamps is significantly lower than it was in 1976 (fig. 13).

The significant decrease in canopy tree density in swamps may be the result of greater hydrologic variability in recent years. Hydrologic conditions have become substantially drier during periods of low and medium flows, which occur about 80 percent of the time. River levels have remained relatively unchanged, however, during large floods 2,830 m^3/s (100,000 ft^3/s) and greater that still occur about three times per decade. The overall effect is that the range in hydrologic conditions is greater, which intensifies the natural alternating cycles of tree colonization during droughts, followed by decimation of tree seedlings and saplings during floods. Drier species cannot fully replace the declining swamp species, and former swamps may be too dry for as many swamp trees to survive as in the past, with the result that fewer trees will grow to maturity in the lower elevations of the floodplain. A lower density of these canopy trees in swamps will result in increased light reaching the swamp floor, thereby encouraging a thicker growth of herbaceous plants, as already seen at many locations in 2004. When ground-cover plants compete with tree seedlings for light and available soil moisture, successful forest replacement in swamps is further reduced. Similar impacts may be occurring to a lesser degree in Loblh forests, because declines were reported for both basal area and density in Loblh forests (fig. 13), although neither was statistically significant.

The large loss in density in swamps could likely lead to future declines in biomass. Large trees are not gaining basal area in swamps (fig. 13), and their eventual replacements will come from the present small canopy and subcanopy, both of which are significantly less dense than the 1976 canopy. The ecological effects of declines in density or biomass are different than those described earlier for changes in species composition. A large decline in biomass would ultimately affect all organisms that have evolved with life cycles dependent on the normal structure of a swamp forest—closely spaced trees with a closed canopy and an inundated forest floor under heavy shade. A decrease in canopy cover would increase the amount of sunlight reaching swamp ground surfaces, causing soils to become dehydrated more frequently and leaf litter and other debris to decompose more quickly in the aerobic environment, thereby reducing the amount of organic material added to floodplain soils or transported downstream by floods. The temperature of inundated soils in swamps would be elevated by the loss of water and exposure to sunlight, further altering the microclimates for soil organisms on the swamp floor. In addition, the volume of forest litter is a function of tree biomass, which has historically been higher in swamps than in bottomland hardwood forests. The loss of litter from lower densities of swamps trees would result in a net loss of substrate for benthic organisms in the inundated areas of the floodplain and, ultimately, in the downstream receiving waters of the river and estuary.

Summary

The effect of water-level declines on floodplain forests is an important issue to be considered in resolving conflicts about water availability in the Apalachicola-Chattahoochee-Flint basin. This study was conducted by the U.S. Geological Survey (USGS) with the cooperation of the Florida Department of Environmental Protection (FDEP) and the Northwest Florida Water Management District (NWFWMD) to assess changes that have occurred in forests in the nontidal floodplain of the Apalachicola River.

Forest composition and field observations from two studies conducted in 1976-79 (1976 data) and two additional studies (1978-84) were used as baseline data for comparison with data from plots sampled in 2004-06 (2004 data). Out of the 95 plots sampled in 2004, 71 were replicate plots that were located at the same, or as close as possible to, the location of 71 of the 181 plots sampled in 1976.

Rules for determining forest types were developed using a factor developed in this study named the Floodplain Species Category (FSC). FSCs were based on the habitat where tree species typically grew on the Apalachicola River floodplain in 1976. FSC1 species were dominant in swamps; FSC2 species were dominant in low bottomland hardwood (Loblh) forests; FSC3 species were dominant in high bottomland hardwood (Hiblh) forests; and FSC4 species were atypical of bottomland hardwoods and grow in upland forests. Forest types determined for 1976 forests were used to assign forest types to 2004 plots.

A Floodplain Index (FI), calculated from the relative dominance of tree species, was developed to quantify species composition of forest plots on a scale of relative dryness. FI values have a range from 1.000 (pure swamp) to 4.000 (upland forests). A difference of + 0.500 in the FI was a change of 50 percent of the species composition toward the next drier forest type. FIs were used to compare the composition of canopy trees on replicate plots and to compare tree-size classes within plots.

Water levels have declined in the Apalachicola River since 1954 as a result of both erosion of the river channel locally, and decreased spring and summer flows from the upstream watershed. Water-level declines have been most severe during drought conditions in April, May, July, and August. Water levels have not declined appreciably during large floods, which continue to occur as frequently as they did prior to 1954.

The inundation history at all plots was estimated based on river stages at transects where plots were sampled. Although several hydrologic parameters were computed, only one parameter, flood duration in the growing season, was used to analyze hydrologic change in the forest, because all parameters were calculated from the same river-stage data and were highly correlated to each other. Flood durations calculated from river stage are reasonably accurate for actual conditions in bottomland hardwood forests, but are not reliable for conditions in many swamps due to individual site characteristics. Observations at the Sweetwater transect in 1976 and 2004 indicated a general lowering of ponded water in swamps located there. Flood durations were calculated for all plots using five time periods associated with 1976 and 2004 tree-size classes.

Species dominance in forest types based on basal area has changed less from 1976 to 2004 than dominance based on tree density. Several FSC3 species that were not dominant in 1976 Loblh forests were dominant species by density in 2004. Water oak was a new dominant species by basal area and density in 2004 Hiblh forests.

There were 4.3 million (17 percent) fewer canopy trees in 2004 than in the 1976 nontidal floodplain forest. The greater part of this loss was in swamp species (water tupelo, popash, Ogeechee tupelo, and bald cypress) which lost an estimated 3.3 million trees. Large decreases in numbers of trees were estimated to be at least 19 percent for water tupelo, 38 percent for popash, and 44 percent for Ogeechee tupelo (the species valuable to the tupelo honey industry).

American holly was the most frequently encountered species on 2004 forest plots that was not observed in 1976 data. American holly is a bottomland hardwood tree that is generally found growing in the higher elevations of Hiblh forests on north Florida floodplains. Silverbell, a tree that grows in upland forests, and American snowbell, a small wetland tree that was formerly found only in the tidal floodplain of the Apalachicola River, were also new species in 2004 nontidal floodplain forests.

The density of trees in swamps significantly decreased by 37 percent from 1976 to 2004. The loss of canopy cover in swamps may be responsible for an increase in ground cover. Some swamps that were known to be nearly bare of ground cover in 1976 were densely covered with grasses and sedges in 2004. When species in each forest type were grouped by FSCs, the changes in density from the 1976 canopy to the 2004 canopy and subcanopy were significantly toward drier forest compositions in Loblh forests and swamps.

Growth, tree size, age, mortality, and recruitment for species and forest types were calculated from replicate plot data from thesis plots. The average growth rate of all species was 0.38 cm/yr. Mortality and recruitment rates between 1976 and 2004 were approximately equal (1.3 percent per year). Four species dominant in Hiblh forests had higher recruitment rates in Loblh than in Hiblh forests.

Using FIs to represent composition, replicate plots were 4.4 percent drier in 2004. Swamps were the most affected forest type and were 8.8 percent drier in 2004 than in 1976.

At 21 plots sampled in 1976, the average FI value for canopy trees was significantly drier (2.8 percent) than the FI value for large canopy trees, indicating that forest composition had become drier when sampled in 1976 than the forest composition was prior to 1954. On 2004 forest plots, small canopy trees averaged 10.5 percent drier and subcanopy trees averaged 31.0 percent drier than the canopy trees. Average differences between subcanopy trees and canopy trees were highly significant for all 2004 plots combined by reach or forest type.

Differences in FI values for tree-size classes on the Suwannee, Ochlockonee, Aucilla, St. Marks, and Telogia floodplains suggest that forest composition also may be drying on other north Florida floodplains, but combined results from all five rivers were not statistically significant, and the amount of drying was less than that documented on the Apalachicola River floodplain. Differences in size classes on the Suwannee River plots were most similar to those on the Apalachicola River plots, which may indicate lower water levels in the Suwannee River.

Changes in flood durations toward the durations of the next drier forest type are substantial in all forest types in all reaches with every advancing time period. Total changes in flood durations were greatest in the upper reach and smallest in the lower reach. At sampled plots in all forest types and reaches combined, flood durations changed an average of 70.4 percent toward the flood duration of the next drier forest type.

Forest composition changes from pre-1954 to 1976 were calculated from the difference in FIs between the 1976 canopy and 1976 large canopy trees, which represented the pre-1954 canopy composition. The change from 1976 to 2004 was based on the difference between FIs of canopy trees at replicated plots, and the potential composition of future forests in 2085 – the year in which the median age of surviving 2004 subcanopy trees will reach the median age (99 years) of the 2004 large canopy trees – was estimated from the composition of 2004 subcanopy trees.

Floodplain forests are expected to average 38.2 drier in species composition by 2085 compared with the pre-1954 period. FI differences (45.0 percent) were larger for upper-reach forests than those for any other reach or all forests combined. The shift to drier hydrologic conditions has preceded the shift to drier forest compositions, and forest composition is expected to be more than 38 percent drier in the decades beyond 2085.

Drier Hiblh forests will support species like water oak and American holly that are able to survive flooding but are well adapted to upland habitats. The competition between Hiblh and Loblh species will increase in drier Loblh forests and some will become Hiblh forests. The altered species composition in drier floodplain forests will alter the timing of leaf-out, fruiting, and leaf-drop, and this change will have consequences for mammals, birds, and invertebrates in floodplains. In swamps there will be some increase in the proportion of Loblh and Hiblh species, but the overall density of trees will be much less than it was in 1976.

The large decrease in canopy tree density in swamps may be the result of greater hydrologic variability in recent years. Conditions have become substantially drier during periods of low and medium flows, which occur about 80 percent of the time, but river levels are relatively unchanged during large floods. Swamp tree species have declined, but drier species cannot dependably survive large floods. The decrease in tree density will result in an increase in light on the forest floor, thereby encouraging a thicker growth of ground-cover plants which, in turn, will further reduce the success of forest replacement.

Lower tree density in swamps could lead to future declines in tree and leaf litter biomass. Declines in biomass would ultimately affect all organisms that have evolved with life cycles that are dependent on the normal structure of the swamp forests. A decrease in canopy cover would expose the swamp floor to light, thereby increasing evaporation from the soil, and speeding up the decomposition of leaf litter. The temperature of swamp soils would be higher, altering microclimates for soil organisms. The decrease in leaf litter would result in a net loss of substrate for benthic organisms in the floodplain, and ultimately, in the downstream waters of the river and estuary.

Selected References

Applequist, M.B., 1959a, A study of soil and site factors affecting the growth and development of swamp blackgum and tupelogum stands in southeastern Georgia: Durham, N.C., Doctoral Thesis, School of Forestry, Duke University.

Applequist, M.B., 1959b, Longevity of submerged tupelo gum and bald cypress seed: Louisiana State University, Forestry Notes 27, 2 p.

Avery, T.E., 1967, Forest measurements: New York, McGraw-Hill, 290 p.

Brinson, M.M., 1990, Riverine forests, *in* Lugo, A.E., Brinson, M., and Brown, S., eds., Ecosystems of the world—Forested Wetlands (v. 15): Elsevier Science, p. 87-141.

Brinson, M.M., Swift, B.L., Plantico, R.C., and Barclay, J.S., 1981, Riparian ecosystems: Their ecology and status: U.S. Fish and Wildlife Service, FWS/OBS-81/17, 155 p.

Brown, C.A., 1984, Morphology and biology of cypress trees, *in* Ewel, K.C., and Odum, H.T., eds., Cypress swamps: Gainesville, University Presses of Florida, p. 16-24.

Carter, Virginia, 1996, Wetland hydrology, water quality, and associated functions, *in* Fretwell, J.D., Williams, J.S., and Redman, P.J., compilers, National water summary on wetland resources: U.S. Geological Survey Water-Supply Paper 2425, p. 35-48.

Clark, J.R., and Benforado, J., eds., 1981, Wetlands of bottomland hardwood forests—Proceedings of a workshop on bottomland hardwood forest wetlands of the southeastern United States, Lake Lanier, Georgia, June 1-5, 1980: Elsevier, Developments in Agricultural and Managed-Forest Ecology, v. 11, p. 335-357.

Clewell, A.F., 1985, Guide to the vascular plants of the Florida Panhandle: Tallahassee, Florida State University Press, 605 p.

Conner, W. H., and Day, J.W., Jr., 1992: Diameter growth of *Taxodium distichum* (L.) Rich. and *Nyssa aquatica* L. from 1979-1985 in four Louisiana swamp stands, American Midland Naturalist, v. 127, p. 290-299.

Darst, M.R., Light, H.M., and Lewis, L.J., 2002, Ground-cover vegetation in wetland forests of the lower Suwannee River floodplain, Florida, and potential impacts of flow reductions: U.S. Geological Survey Water-Resources Investigations Report 02-4027, 46 p.

Davis, M.M., Mitchell, W.A., Wakeley, J.S., Fischenich, J.C., and Craft, M.M., 1996, Environmental value of riparian vegetation: U.S. Army Corps of Engineers, Technical Report EL-96-16, 147 p., plus appendixes.

Dickson, R.E., Hosner, J.F., and Hosley, N.W., 1965, The effects of four water regimes upon the growth of four bottomland tree species: Forest Science, v. 11, no. 3, p. 299-305.

Eichholz, N.F., Bailey, D.B., and McGehee, A.V., 1979, An investigation of dredged material disposal sites on the lower Apalachicola River: Tallahassee, Florida Game and Freshwater Fish Commission, Office of Environmental Services, 115 p.

Eyre, F.H., ed., 1980, Forest cover types of the United States and Canada: Washington, D.C., Society of American Foresters, 148 p.

Fowells, H.A., compiler, 1965, Silvics of forest trees of the United States (revised): Washington, D.C., U.S. Department of Agriculture, Forest Service, Agriculture Handbook No. 271, 762 p.

Gholson, A.K., Jr., 1985, Vegetation analysis for the Apalachicola River Maintenance Dredging Disposal Site Evaluation Study: Mobile, U.S. Army Corps of Engineers, 203 p.

Godfrey, R.K., 1988, Trees, shrubs, and woody vines of northern Florida and adjacent Georgia and Alabama: Athens, The University of Georgia Press, 734 p.

Gosselink, J.G., Lee, L.C., and Muir, T.A., eds., 1990, Ecological processes and cumulative impacts: Chelsea, Mich., Lewis Publishers, 708 p.

Greeson, P.E., Clark, J.R., and Clark, J.E., eds., 1979, Wetland functions and values: The state of our understanding—Proceedings of the national symposium on wetlands, Lake Buena Vista, Florida, November 1978: Minneapolis, American Water Resources Association, Technical Publication Series TPS79-2, 674 p.

Harms, W.R., 1973, Some effects of soil type and water regime on growth of tupelo seedlings: Ecology, v. 54, no. 1, p. 188-193.

Hook, D.D., and Crawford, R.M.M., eds., 1978, Adaptations and flood tolerance of tree species, *in* Plant life in anaerobic environments: Ann Arbor, Mich., Ann Arbor Science Publishers, p. 299-331.

Hosner, J.F., 1960, Relative tolerance to complete inundation of fourteen bottomland tree species: Forest Science, v. 6, no. 3, p. 246-251.

Klimas, C.V., 1988, River regulation effects on floodplain hydrology and ecology, *in* Hook, D.D., and others, eds., The ecology and management of wetlands, v. 1: Croom Helm, London, 592 p.

Kulow, D.L., 1965, Elementary point-sampling: Morgantown, West Virginia University, Agriculture Experiment Station, Circular 116, 24 p.

*Leitman, H.M., 1978, Correlation of Apalachicola floodplain tree communities with water levels, elevation, and soils: Unpublished master's thesis, Tallahassee, Florida State University.

*H.M. Leitman is the previous name of H.M. Light, the second author of this report.

*Leitman, H.M., 1984, Forest map and hydrologic conditions, Apalachicola River floodplain, Florida: U.S. Geological Survey Hydrologic Investigations Atlas HA-672.

*Leitman, H.M., Sohm, J.E., and Franklin, M.A., 1984, Wetland hydrology and tree distribution of the Apalachicola River flood plain, Florida: U.S. Geological Survey Water-Supply Paper 2196-A, 52 p.

Light, H.M., Darst, M.R., Lewis, L.J., and Howell, D.A., 2002, Hydrology, vegetation, and soils of riverine and tidal floodplain forests of the lower Suwannee River, Florida, and potential impacts of flow reductions: U.S. Geological Survey Professional Paper 1656-A, 124 p.

Light, H.M., Darst, M.R., MacLaughlin, M.T., and Sprecher, S.W., 1993, Hydrology, vegetation, and soils of four north Florida river flood plains with an evaluation of State and Federal wetland determinations: U.S. Geological Survey Water-Resources Investigations Report 93-4033, 94 p.

Light, H.M., Vincent, K.R., Darst, M.R., and Price, F.D., 2006, Water-level decline in the Apalachicola River, Florida, from 1954 to 2004, and effects on floodplain habitats: U.S. Geological Survey Scientific Investigations Report 2006-5173, 52 p., *http://pubs.usgs.gov/sir/2006/5173/*

Lugo, A.E., Brinson, M., and Brown, S., eds., 1990, Ecosystems of the world—Forested Wetlands: Elsevier, v. 15, 527 p.

Messina, M.G., and Conner, W.H., eds., 1998, Southern forested wetlands—Ecology and management: New York, Louis Publishers, 616 p.

Mitsch, W.J., and Gosselink, J.G., 2000, Wetlands (3d ed.): New York, John Wiley, 920 p.

Mueller-Dombois, Dieter, and Ellenberg, Heinz, 1974, Aims and methods of vegetation ecology: New York, John Wiley, 547 p.

Oertel, E., 1934, White tupelo of western Florida: American Bee Journal, v. 74, p. 310-312.

Palta, M.M., Richardson, E.A., and Sharitz, R.R., 2003, Effects of altered flow regimes on floodplain forest processes in the Savannah River basin—Proceedings of the 2003 Georgia Water Resources Conference, University of Georgia, Georgia, April 2003: Athens, Institute of Ecology, University of Georgia, 674 p.

Puri, H.S., and Vernon, R.O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures (revised): Tallahassee, Florida Geological Survey, Special Publication 5, 312 p.

Rahmlow, H.J., 1960, Tupelo honey production: Gleanings in bee culture, v. 88, p 457-461.

Reed, P.B., Jr., 1988, National list of plant species that occur in wetlands: 1988 – Florida: St. Petersburg, Florida, National Wetlands Inventory, U.S. Fish and Wildlife Service, 140 p.

Shimano, K., 2000, A power function for forest structure and regeneration pattern of pioneer and climax species in patch mosaic forests: Plant Ecology, v. 146, p. 207-220.

Smith, Matt, 2007, Assessing the response of an alluvial floodplain forest to dam-induced hydrologic change (Apalachicola River, Florida, USA): Unpublished master's thesis, Tallahassee, Florida State University.

Wentworth, T.R., Johnson, G.P., and Kologiski, R.L., 1988, Designation of wetlands by weighted averages of vegetation data: A preliminary evaluation: Water Resources Bulletin, v. 24, no. 2, p. 389-396.

Wharton, C.H., Kitchens, W.M., and Sipe, T.W., 1982, The ecology of bottomland hardwood swamps of the southeast: A community profile: U.S. Fish and Wildlife Service FWS/OBS-81/37, 133 p.

Glossary

Basal area is the average sum of the cross-sectional areas of tree trunks for plots or species in a forest type. Cross-sectional area is calculated from diameter at breast height (dbh), in centimeters, using the formula, area = πr^2, where $\pi = 3.1416$ and r = dbh/2. (See **relative basal area**.)

Bottomland hardwoods are forests on levees, flats, and slopes of floodplains that are flooded continuously for several weeks or longer every 1-2 years and contain species adapted to periodic inundation and saturation.

Low bottomland hardwood (**Loblh**) forests grow on low flats and in transition areas between swamps and high flats or levees where continuous flooding averages 2 to 4 months per year. **Loblh** is a forest type, defined in this report as having dominance (as determined by relative basal area) of FSC1 and FSC2 species > dominance of FSC3 and FSC4 species and dominance of FSC1 species < 50%.

High bottomland hardwood (**Hiblh**) forests grow on the higher elevations of the floodplain (levees and ridges) that are usually inundated for 2 to 6 weeks each year. **Hiblh** is a forest type, defined in this report as having dominance (as determined by relative basal area) of FSC3 and FSC4 species > dominance of FSC1 and FSC2 species and dominance of FSC4 species < 50%.

Cruise transects are floodplain sites where forest composition data was gathered by Leitman and others (1984) using cruise-sampling methods that were originally developed to enable timber cruisers to rapidly assess the overall condition of large forest stands by sampling at many points (Kulow, 1965; Avery, 1967). (See intensive plots.)

Density is the number of individual trees per unit of sampling area and in this report is expressed in trees per hectare. (See **relative density**.)

Diameter at breast height (dbh) is the diameter of a tree trunk measured at about 1.4 meter above ground level. The dbh of trees with swollen bases were measured for diameter above the swelling.

Floodplain is the land covered by water from the river during a typical annual flood.

Floodplain Index (FI) is the sum of the products of the relative basal area of species (or relative density) and their Floodplain Species Categories. FIs were developed in this study to classify forest data on a scale of relative dryness from pure swamp (1.000) to pure upland (4.000).

Floodplain Species Categories (FSC) are categories developed in this study and assigned to tree species to indicate the typical habitat where the species grew on the Apalachicola River floodplain during 1976-79. FSC1 species were more dominant in swamps; FSC2 species, in low bottomland hardwoods; FSC3 species, in high bottomland hardwoods; and FSC4 species were atypical in bottomland hardwoods and occur in upland habitats outside the floodplain.

Gage refers to a long-term streamflow gaging station where a time-series of stage measurements (elevation of river surface) have been recorded, and measurements of instantaneous streamflow discharge may have been made.

Geographic Information system (GIS) is a collection of computer software and data files designed to store, analyze, and display geographically referenced information.

1976 forest data refers to data collected from 1976 to 1979 in two studies conducted on the Apalachicola River floodplain.

2004 forest data refers to data collected during the current study from 2004 to 2006 in the Apalachicola River floodplain.

Intensive plots are floodplain sites where forests were sampled using standard plot-sampling methods to quantify forest composition in more detail than is possible using cruise-sampling methods. (See cruise transects.)

Reach refers to a length-subdivision of the Apalachicola River (fig. 2).

> The **upper reach** begins just below Jim Woodruff Dam at rm 106.4 and extends about 47 km downstream to a streamflow gaging station located near Blountstown at rm 77.5.
>
> The **middle reach** is the longest reach, about 58 km long, ending at a gage near Wewahitchka at rm 41.8.
>
> The nontidal **lower reach** is the shortest reach, about 34 km long, and ends at a gage near Sumatra at rm 20.6. The tidal reach of the river is not discussed in this report.

Relative basal area (rba) is the percentage of dominance of a species in a forest type or sampling area based on basal area. It is calculated by dividing the total basal area of that species by the total basal area of all species in that forest type or sampling plot. (See **basal area**.)

Relative density (rd) is the percentage dominance of a species in a forest type or sampling area based on density. It is calculated by dividing the total density of that species by the total density of all species in that forest type or sampling plot. (See **density**.)

Replicate plot is a plot sampled in 1976 that was resampled in 2004 by locating the 2004 plot on the exact site, as nearly as possible, as the 1976 site location.

River mile (rm) refers to a reference frame based on distances along the river channel. In this report, river mile values are those depicted on the most recent USGS quadrangle maps that were available in 2005. River mile distances are similar to, but not exactly the same as, the most recent navigation mile system used by USACE. Slight differences in distance reference frames are to be expected, because the river moves and changes length through time in response to various processes, both natural and anthropogenic.

Swamps are forests in the lowest elevations of the floodplain that are either inundated or saturated most of the time. Swamps contain tree species that have special adaptations for survival in anoxic soils. **Swamp** is also a forest type, defined in this report as having dominance (as determined by relative basal area) of FSC1 species $\geq$ 50 percent.

Tree-size classes are trees grouped by diameter at breast height (dbh). Trees in this study have been grouped by their dbh into two principal groups:

> **Canopy trees** are all trees with dbh $\geq$ 7.5 cm.
>
> **Subcanopy trees** are trees with dbh < 7.5 and $\geq$ 2.5 cm.
>
> The canopy size class is further subdivided into two size classes:
>
> > **Large canopy trees** are trees with dbh $\geq$ 25 cm.
> >
> > **Small canopy trees** are trees with dbh < 25 and $\geq$ 7.5 cm.

Water-level decline (or river level decline) is a term referring to changing conditions when periods of low water levels become more frequent and longer in duration. Such declines may result from some type of channel change, which usually occurs over a period of years. Another type of water-level decline refers to a long-term decrease in the amount of water delivered from the upstream watershed.

Appendixes

Appendix 1. List of common and scientific names and Floodplain Species Categories for selected tree species in forests of the nontidal Apalachicola River floodplain, Florida.

[All tree species sampled in the 1976 and 2004 data sets are listed. Additional species not included in this list occur on the Apalachicola River floodplain. Plant nomenclature follows Godfrey (1988) unless otherwise indicated. Floodplain Species Categories are based on the typical forest association for the species in 1976 data. Atypical blh-upl, uncommon in bottomland hardwoods of the 1976 floodplain and occurring in upland habitats outside the floodplain; Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods]

Common name	Scientific name	Floodplain species category	
		Numeric value	Category explanation
American elm	*Ulmus americana*	2	Loblh
American holly	*Ilex opaca*	3	Hiblh
American snowbell	*Styrax americanum*	2	Loblh
bald cypress	*Taxodium distichum*	1	swamp
bitternut hickory	*Carya cordiformis*	3	Hiblh
black tupelo	*Nyssa sylvatica*	4	Atypical blh-upl
black walnut	*Juglans nigra*	4	Atypical blh-upl
black willow	*Salix nigra*	1	swamp
box elder	*Acer negundo*	3	Hiblh
buckthorn bumelia	*Bumelia lycioides*	3	Hiblh
buttonbush	*Cephalanthus occidentalis*	1	swamp
cherry laurel	*Prunus caroliniana*	4	Atypical blh-upl
cherrybark oak	*Quercus pagoda*	3	Hiblh
chinaberry	*Melia azedarach*	4	Atypical blh-upl
Chinese tallow tree	*Sapium sebiferum*	3	Hiblh
elderberry	*Sambucus canadensis*	3	Hiblh
green ash	*Fraxinus pennsylvanica*	2	Loblh
green haw	*Crataegus viridis*	2	Loblh
hackberry	*Celtis laevigata*	3	Hiblh
hazel alder	*Alnus serrulata*	2	Loblh
ironwood	*Carpinus caroliniana*	3	Hiblh
laurel oak	*Quercus hemispherica*	4	Atypical blh-upl
loblolly pine	*Pinus taeda*	4	Atypical blh-upl
mockernut hickory	*Carya tomentosa*	4	Atypical blh-upl
Ogeeche tupelo	*Nyssa ogeche*	1	swamp
overcup oak	*Quercus lyrata*	2	Loblh
persimmon	*Diospyros virginiana*	3	Hiblh
pignut hickory	*Carya glabra*	4	Atypical blh-upl
planer tree	*Planera aquatica*	1	swamp
popash	*Fraxinus caroliniana*	1	swamp
possum haw	*Ilex decidua*	3	Hiblh
red maple	*Acer rubrum*	2	Loblh
red mulberry	*Morus rubra*	3	Hiblh
river birch	*Betula nigra*	2	Loblh
sarvis holly	*Ilex amelanchier*	1	swamp
silverbell	*Halesia diptera*	4	Atypical blh-upl
slippery elm	*Ulmus rubra*	4	Atypical blh-upl
southern magnolia	*Magnolia grandiflora*	4	Atypical blh-upl
spruce pine	*Pinus glabra*	3	Hiblh
stiffcornel dogwood	*Cornus foemina*	2	Loblh
swamp chestnut oak	*Quercus michauxii*	3	Hiblh
swamp cottonwood	*Populus heterophylla*	1	swamp
swamp laurel oak	*Quercus laurifolia*	2	Loblh
swamp privet	*Forestiera acuminata*	2	Loblh
swamp tupelo	*Nyssa biflora* [a]	1	swamp
sweetbay	*Magnolia virginiana*	3	Hiblh
sweetgum	*Liquidambar styraciflua*	3	Hiblh
sycamore	*Platanus occidentalis*	3	Hiblh
water hickory	*Carya aquatica*	2	Loblh
water locust	*Gleditsia aquatica*	2	Loblh
water oak	*Quercus nigra*	3	Hiblh
water tupelo	*Nyssa aquatica*	1	swamp
white titi	*Cyrilla racemiflora*	3	Hiblh
winged elm	*Ulmus alata*	4	Atypical blh-upl
winterberry	*Ilex verticillata*	2	Loblh

[a] Clewell (1985).

Appendix 2. Weighting factors for forest composition on the Apalachicola River floodplain, Florida.

[Areas were derived from a digitized and edited GIS version of a floodplain map created by Leitman (1984), in which Hiblh and Loblh forest types were not separately delineated. The areas of Hiblh and Loblh in the upper and lower reaches were calculated using ratios based on the redetermined 1976 forest types of plots on cruise transects (Leitman and others, 1984). In the lower reach, the ratio was based on 1976 forest types assigned to plots on the Eichholz transects in the current study. ha, hectares; Hiblh, high bottomland hardwoods; Loblh; low bottomland hardwoods]

Reach	Area of Forest Type, in ha				Weighting Factors for Forest Types in each Reach, in percent [a]		
	Hiblh	Loblh	Swamp	Total	Hiblh	Loblh	Swamp
Upper	3,710	1,370	1,612	6,691	**42.3**	**9.2**	**17.0**
Middle	4,040	8,080	1,880	14,001	**46.1**	**54.3**	**19.8**
Lower	1,020	5,430	6,010	12,455	**11.6**	**36.5**	**63.2**
Total	**8,770**	**14,880**	**9,502**	**33,147**			

[a] The weighting factors used for 1976 Hiblh data were 42.3 percent for the upper reach and 57.7 percent for the middle reach, because there was no data on Hiblh forests in the lower reach, and lower reach Hiblh forests were more similar in species composition to Hiblh in the middle reach than to those in the upper reach.

Appendix 3. Extrapolated ages of canopy trees in 2004 at the thesis transects in the Apalachicola River floodplain, Florida.

[Ages of individual trees were extrapolated from the average growth rates for the species and the diameter at breast height. Species are listed in order by increasing average age. Ages were limited to a maximum of 360 years, the calculated age of the largest tree on the thesis transects. Growth rate descriptions are from table 4. Scientific names of species are listed in appendix 1]

Species	Sample size	General description of growth rate	Maximum age, in years	Minimum age, in years	Average age, in years
swamp laurel oak	61	fast	138	18	53
sycamore	7	fast	112	18	63
Ogeechee tupelo	42	average	182	26	65
overcup oak	54	above average	205	23	66
water locust	12	average	130	32	68
winged elm	9	below average	101	47	69
water hickory	58	above average	167	21	71
water tupelo	25	fast	137	30	75
red maple	25	below average	153	35	76
green ash	42	fast	162	23	77
ironwood	48	below average	170	42	77
sweetgum	79	above average	191	23	81
American elm	21	average	166	31	86
hackberry	62	below average	202	33	91
popash	16	slow	151	47	95
planer tree	44	slow	173	57	95
bald cypress	26	above average	360	26	108
river birch	2	above average	150	80	115
box elder	8	slow	234	61	135
green haw	21	slow	265	124	170
possum haw	35	slow	360	205	270
persimmon	4	slow	360	263	331
Total	**701**				
Maximum age			**360**		
Minimum age				**18**	
Average age					**92**

Appendix 4. Number of days of missing record, years during which missing records occurred, and methods of estimating missing records from October 1, 1922, to December 31, 2004, at five streamflow gaging stations in the Apalachicola River, Florida.

[All stage-discharge relations referred to in this appendix, except those at the Chattahoochee gage, are nonstandard relations in which stage at a downstream gage was related to discharge at the upstream-most gage at Chattahoochee. The stage-discharge relations and associated error statistics for these relations are reported in appendixes I-V and table 5 in Light and others (2006). Most of these relations required some modification at the low end [below 283 m^3/s (10,000 ft^3/s)] to extend the relations down to flows lower than 142 m^3/s (5,000 ft^3/s), which was necessary for the estimation methods described in this appendix. rm, river mile]

Short names for streamflow gaging stations:

- Chattahoochee gage – Apalachicola River at Chattahoochee (02358000) at rm 105.7
- Blountstown gage – Apalachicola River near Blountstown (02358700) at rm 77.5
- Wewahitchka gage – Apalachicola River near Wewahitchka (02358754) at rm 41.8
- RM 36 gage – Apalachicola River at River Mile 36 (023587547) at rm 36.0
  Note: Stage records were not reconstructed for the RM 36 gage, although data from that gage were used when available to reconstruct stage data at nearby gages.
- RM 35 gage – Apalachicola River at River Mile 35 (023587549) at rm 35.3
- Sumatra gage – Apalachicola River near Sumatra (02359170) at rm 20.6

Definition of terms:

- Pre-dam relation – pre-dam (pre-1954) stage-discharge relation for the indicated gage modified from appendixes I-V in Light and others (2006).
- Recent relation – recent (1995-04) stage-discharge relation for the indicated gage modified from appendixes I-V in Light and others (2006).
- Intervening period – the period during which channel conditions were intermediate between pre-dam and recent conditions (varies with each gage).
- Blount-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the Blountstown gage.
- Wewa-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the Wewahitchka gage.
- RM 36-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the RM 36 gage.
- RM 35-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the RM 35 gage.
- Suma-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the Sumatra gage.

Discharge at Chattahoochee gage

2,192 total days of missing record, all in 1923-28

Stage at the Chattahoochee gage was converted to discharge using the pre-dam stage-discharge relation at Chattahoochee.

Stage at Chattahoochee gage

159 total days of missing record: 75 days in 1923-25, and 84 days in 1994-04

Fortunately, stage data was available at the Blountstown gage for all days of missing stage record at the Chattahoochee gage. For missing record in the 1923-25 period, Blountstown stage (1 day later) was converted to Blount-ChattQ using the pre-dam relation at Blountstown. For missing record during the 1994-04 period, Blountstown stage (1 day later) was converted to Blount-ChattQ using the recent relation at Blountstown. The resulting Blount-ChattQ values were then converted to Chattahoochee daily mean stage using either the pre-dam or recent relation at the Chattahoochee gage, as appropriate.

Stage at Blountstown gage

716 total days of missing record: 75 days in 1925-28, 46 days in 1956, 38 days in 1963-65, and 557 days in 1981-95

Pre-dam period: Chattahoochee discharge (1 day earlier) was converted to Blountstown stage using the pre-dam relation at Blountstown.

Intervening period (1954-72): For missing record in 1956, linear interpolation (based on river miles) was used between Chattahoochee discharge (1-day earlier) and Wewa-ChattQ (1 day later). The resulting discharge was converted to two Blountstown stage values using the pre-dam and recent relations, and the final Blountstown stage was estimated between those two stages based on the date elapsed since May 1, 1954 (the end of the pre-dam period) and proportions developed from the general timing of stage declines at 283 m^3/s (10,000 ft^3/s) as depicted in figure 5 in Light and others (2006). A similar method was used for estimating stage values for missing record in 1963-65, except that calculations were based only on Chattahoochee discharge (1 day earlier) because Wewahitchka data was not available.

Recent period: Figure 5 in Light and others (2006) indicates that conditions at the Blountstown gage were similar to recent conditions as far back as 1972. Thus the recent relation was used to estimate stages at the Blountstown gage throughout the 1972-04 period. Missing stage records in 1981-95 were estimated using Chattahoochee discharge (1 day earlier) converted to Blountstown stage using the recent relation at Blountstown. (Wewahitchka data was not available for any of those days.)

Stage at Wewahitchka gage

19,080 total days of missing record: 12,053 days (all days) prior to October 18, 1955; 49 days in 1956-57; 5,759 days in 1957-94; and 1,219 days in 1995-04

Pre-dam period: Conditions were considered similar to pre-dam for all dates up through 1957 at the Wewahitchka gage (Light and others, 2004). For estimated record during 1922-57, Blount-ChattQ (1 day earlier) was converted to Wewahitchka stage using the pre-dam relation at Wewahitchka, except on dates when stage data was available at the Sumatra gage. When Sumatra data was available, linear interpolation (based on river miles) between Blount-ChattQ (1 day earlier) and Suma-ChattQ (1 day later) was used to estimate Wewa-ChattQ, which was then converted to Wewahitchka stage using the pre-dam relation at the Wewahitchka gage.

Intervening period (1958-94): When Sumatra data was available, linear interpolation between Blount-ChattQ (1 day earlier) and Suma-ChattQ (1 day later) was used to estimate Wewa-ChattQ, which was then converted into two Wewahitchka stage values using the pre-dam and recent relations at the Wewahitchka gage. The final Wewahitchka stage was estimated between those two stages based on the date elapsed since October 1, 1957 (the end of the pre-dam period for Wewahitchka) and proportions developed from the general timing of stage changes at 283 m^3/s (10,000 ft^3/s) as depicted in figure 5 in Light and others (2006). In some cases, calculations were based only on Blount-ChattQ (1 day earlier) because Sumatra data was not available. In 1992-94, calculations were based directly on RM 36-ChattQ (same day) when it was available, because it is much closer to the Wewahitchka gage than either Blountstown or Sumatra.

Recent period: Missing records in 1995-04 were estimated using RM 35-ChattQ or RM 36-ChattQ (same day), which was converted to Wewahitchka stage using the recent stage-discharge relation. When RM 35 or 36 data was not available, calculations used either linear interpolation between Blount-ChattQ and Suma-ChattQ, or if Sumatra was not available, Blount-ChattQ alone.

Stage at RM 35 gage

26,346 total days of missing record: 25,202 days (all days) prior to October 1, 1991; and 1,144 days in 1992-04

Pre-dam period: All dates up through 1957 were considered pre-dam at the RM 35 gage (same as at Wewahitchka). For missing record during 1922-57, Blount-ChattQ (1 day earlier) was converted to RM 35 stage using the pre-dam relation at RM 35, except on dates when stage data was available at either the Wewahitchka or Sumatra gages. Wewa-ChattQ was used directly when Wewahitchka data was available, and when Sumatra data was available (but not Wewahitchka), the calculation was based on linear interpolation between Blount-ChattQ (1 day earlier) and Suma-ChattQ (1 day later).

Intervening period (1958-80): Firstly, RM35-ChattQ was estimated using one of three methods: 1) When Wewahitchka stage data was available, Wewa-ChattQ (same-day) was used directly. 2) When Sumatra data was available (but not Wewahitchka), linear interpolation between Blount-ChattQ (1 day earlier) and Suma-ChattQ (1 day later) was used. 3) When the only data available was at Blountstown, Blount-ChattQ (1 day earlier) was used directly. In the next step, the resulting RM 35-ChattQ was converted into two RM 35 stages using the pre-dam and recent relations at the RM 35 gage. Lastly, the final RM 35 stage was estimated between those two stages based on the date elapsed since October 1, 1957, (the end of the pre-dam period for RM 35) and proportions developed from a straight-line decline of stages at 283 m^3/s (10,000 ft^3/s) from pre-dam conditions to the recent condition beginning in October 1, 1980.

Recent period: Records at the RM 35 and 36 gages were not available prior to 1992, however, stage-discharge relations from the USACE (2001) indicated that conditions similar to those in the recent period extended as far back as 1981. Missing record from 1981-04 were estimated using Wewa-ChattQ (same day) which was converted to RM 35 stage using the recent relation at the RM 35 gage. When Wewahitchka data was not available, linear interpolation between Blount-ChattQ (1 day earlier) and Suma-ChattQ (1 day later) was used, or Blount-ChattQ only when Sumatra data was not available.

Stage at Sumatra gage

17,277 total days of missing record: 10,084 days (all days) prior to May 11, 1950; 283 days in 1951-56; 6,545 days (all days) from October 1, 1959 to August 31, 1977; and 365 days from 1982-03.

There was little difference in pre-dam and recent channel conditions at the Sumatra gage, so the stage-discharge relation at Sumatra covers the entire period of record. This "period-of-record" relation was used to convert Blount-ChattQ (2 days earlier) to Sumatra stage, except on dates when stage data was available at either the Wewahitchka, RM 36, or RM 35 gages. In that case, the associated Chattahoochee discharge (Wewa-ChattQ, RM 36-ChattQ, or RM 35-ChattQ; 1 day earlier) for the gage that was closest to Sumatra was used to calculate Sumatra stage.

Appendix 5. Methods used to estimate stage records from October 1, 1922, to December 31, 2004, in the Apalachicola River, Florida, at 12 forest transect locations.

[Stage-discharge relations referred to in this appendix are nonstandard relations in which stage at the indicated transect was related to discharge at the upstream-most gage at Chattahoochee. The stage-discharge relations for these relations are reported in digital files on the CD in the map pocket of Light and others (2006). These relations required some modification at the low end (below 283 m^3/s (10,000 ft^3/s)) to extend the relations down to flows lower than 142 m^3/s (5,000 ft^3/s), which was necessary for the estimation methods described in this appendix. rm, river mile; km, kilometer]

Definition of terms:

- Type 1 interpolation -- Linear interpolation (based on river miles) between closest upstream gage (same day) and closest downstream gage (1 day later).
- Type 2 interpolation -- Linear interpolation (based on river miles) between closest upstream gage (1 day earlier) and closest downstream gage (same day).
- Type 3 interpolation -- Linear interpolation (based on river miles) between closest upstream gage (same day) and closest downstream gage (same day).
- Blount-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the Blountstown gage.
- BLT-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the BLT transect.
- MR-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the MR transect.
- PL-ChattQ – Discharge at the Chattahoochee gage associated with a given stage at the PL transect.
- Wewa-ChattQ -- Discharge at the Chattahoochee gage associated with a given stage at the Wewahitchka gage.
- Pre-dam relation – pre-dam (pre-1954) stage-discharge relation for the indicated transect modified from Light and others (2006).
- Recent relation -- recent (1995-04) stage-discharge relation for the indicated transect modified from Light and others (2006).
- Intervening period -- the period during which channel conditions were intermediate between pre-dam and recent conditions.

CH transect (rm 104.8) stage was estimated using Type 1 interpolation between stage at the Chattahoochee and Blountstown gages.

TO transect (rm 93.2) stage was estimated using Type 1 interpolation between stage at the Chattahoochee and Blountstown gages.

SE transect (rm 85.8) stage was estimated using Type 2 interpolation between stage at the Chattahoochee and Blountstown gages.

BLT transect (rm 78.9) stage was estimated using Type 2 interpolation between stage at the Chattahoochee and Blountstown gages, except during the recent period (1995-04) during which Type 2 interpolation between Chattahoochee discharge and Blount-ChattQ was used to estimate BLT-ChattQ, which was then converted into BLT stage using the recent relation for rm 78.9.

OR transect (rm 72.4) stage was estimated using Type 1 interpolation between stage at the Blountstown and Wewahitchka gages.

MR transect (rm 60.9) stages could not be estimated directly from linear interpolation between Blountstown and Wewahitchka stages because water-surface profiles in figure 9 of Light and others (2006) indicates that water surfaces at MR differ from those that would be expected with linear interpolation. Thus, MR stages were estimated as follows:

- MR-ChattQ was estimated by averaging Type 1 and Type 2 interpolations between Blount-ChattQ and Wewa-ChattQ (because MR is approximately half way between the Blountstown and Wewahitchka gages).
- Timing of the pre-dam, intervening, and recent periods was estimated based on two assumptions: Stage decline at MR was assumed to begin about the same time as at the Wewahitchka gage (which was several

years later than it began at Blountstown and Chattahoochee) because MR is downstream of rm 66 (the probable downstream limit of the influence of the dam). It was also assumed that stages at MR did not decline below recent levels as they did at the Wewahitchka gage after 1971, thus recent conditions at MR were assumed from December 1971 through 2004.

- Prior to October 1, 1957, MR-ChattQ was converted to MR stage using the pre-dam relation for rm 60.9. After December 18, 1971, MR-ChattQ was converted to MR stage using the recent relation for rm 60.9. In the intervening period, MR-ChattQ was converted to two stages (pre-dam and recent) and the final MR stage was estimated between those two stages based on the date elapsed since October 1, 1957, and proportions developed from a straight-line decline of stages at 283 m^3/s (10,000 ft^3/s) from pre-dam conditions ending October 1957 to the recent conditions beginning in December 1971.

PL transect (rm 48.8) stage could not be estimated directly from linear interpolation (for the same reason as for MR stage) and, therefore, was estimated as follows:

- PL-ChattQ was estimated using Type 2 interpolation between Blount-ChattQ and Wewa-ChattQ.
- Timing of the pre-dam, intervening, and recent periods was assumed to be the same as at MR transect (for the same reasons).
- Prior to October 1, 1957, PL-ChattQ was converted to PL stage using the pre-dam relation for rm 48.8. After December 18, 1971, PL-ChattQ was converted to PL stage using the recent relation for rm 48.8. In the intervening period, PL-ChattQ was converted to two stages (pre-dam and recent) and the final PL stage was estimated between those two stages based on the date elapsed since October 1, 1957, and proportions developed from a straight-line decline of stages at 283 m^3/s (10,000 ft^3/s) from pre-dam conditions ending October 1957 to the recent conditions beginning in December 1971.

WEW transect (rm 41.9) stage was estimated using Type 2 interpolation between stage at the Blountstown and Wewahitchka gages.

EA transect (rm 41.2) stage was estimated using Type 3 interpolation between stage at the Wewahitchka and RM 35 gages.

EB transect (rm 40.5) stage was estimated using Type 3 interpolation between stage at the Wewahitchka and RM 35 gages.

EC transect (rm 35.0) stage was estimated using Type 1 interpolation between stage at the RM 35 and Sumatra gages.

BR transect (rm 19.8) is located 1.3 km downstream of the Sumatra gage, and there are no other gages downstream of Sumatra. Water-surface slope in the 1.3 km from rm 20.6 (Sumatra gage) downstream to rm 19.8 (BR transect) was assumed to be the same slope as in the 1.3 km immediately upstream of Sumatra gage (from rm 21.4 to 20.6). Using this assumption, BR stage was estimated as follows:

- Stage at rm 21.4 was estimated using Type 2 interpolation between stage at the RM 35 and Sumatra gages.
- Sumatra stage was subtracted from the stage at rm 21.4, and the resulting difference was then subtracted from Sumatra stage to yield the estimated stage at BR transect.

Appendix 6. Relative basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative basal area (rba) was weighted by the percent of area of each forest type in each reach. The sum of the rba of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; m^2/ha, square meters per hectare; na, not applicable]

Species	Floodplain species category	Relative basal area, in percent			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
A. High bottomland hardwoods					
sweetgum	3	**29.1**	**50.3**	**34.5**	**32.1**
hackberry	3	**17.5**	9.8	**15.6**	**12.5**
ironwood	3	**10.6**	1.6	8.4	4.3
water oak	3	10.4	0.8	8.0	**11.2**
green ash	2	4.9	12.3	7.2	4.5
swamp laurel oak	2	3.7	3.5	3.8	3.4
American elm	2	3.8	1.7	3.6	6.9
possum haw	3	2.9	1.7	3.0	0.6
swamp chestnut oak	3	2.9		2.7	1.1
water hickory	2	2.0	6.8	2.6	4.9
sycamore	3	2.6	4.4	2.4	2.3
box elder	3	1.8	1.7	2.0	2.5
swamp privet	2	1.2	0.2	1.2	
overcup oak	2	0.9	1.4	1.1	1.3
red maple	2	0.7	1.3	0.8	0.7
red mulberry	3	0.9	0.3	0.5	0.3
chinaberry	4	0.5	1.1	0.5	0.7
winged elm	4	0.7	0.2	0.4	2.0
pagoda oak	3	0.6		0.3	
green haw	2	0.4	0.3	0.2	0.1
swamp tupelo	1	0.4		0.2	1.7
spruce pine	3	0.4		0.2	
bald cypress	1	0.3		0.1	
black tupelo	4	0.3		0.1	
slippery elm	4	0.3		0.1	0.3
buckthorn bumelia	3	0.2		0.1	0.1
loblolly pine	4	0.2		0.1	
persimmon	3		0.3	0.1	0.8
river birch	2		0.2	0.05	0.8
black walnut	4		0.1	0.02	
American holly	3				2.4
bitternut hickory	3				1.6
southern magnolia	4				0.3
silverbell	4				0.3
planer tree	1				0.1
Ogeechee tupelo	1				0.1
Chinese tallow tree	3				0.03
cherry laurel	4				0.02
popash	1				0.02
Total		100.0	100.0	100.0	100.0
Average total basal area, in m^2/ha		26.4	28.1	27.0	28.5
Number of canopy trees sampled		352	283	635	671
Total area sampled, in ha		na	0.49	na	1.22
Number of species		27	21	30	30

Appendix 6. (Continued) Relative basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative basal area (rba) was weighted by the percent of area of each forest type in each reach. The sum of the rba of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; m^2/ha, square meters per hectare; na, not applicable]

Species	Floodplain species category	Relative basal area, in percent			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
B. Low bottomland hardwoods					
water hickory	2	**9.9**	**27.5**	**18.3**	**19.1**
overcup oak	2	**19.1**	9.0	**14.3**	**11.5**
swamp laurel oak	2	6.5	**16.5**	**11.2**	**11.3**
green ash	2	**10.0**	**11.9**	**10.9**	**9.3**
American elm	2	**11.0**	3.4	7.4	7.2
river birch	2	**9.4**	3.6	6.6	4.6
Ogeechee tupelo	1	8.1	3.3	5.8	5.6
sweetgum	3	6.3	3.3	4.9	6.9
hackberry	3	3.2	4.2	3.7	4.6
water tupelo	1	4.3	1.2	2.8	4.5
ironwood	3	2.5	2.7	2.6	1.7
red maple	2	2.5	1.2	1.9	2.7
bald cypress	1	0.9	2.3	1.5	3.0
water oak	3	1.1	1.6	1.3	0.3
black willow	1		2.4	1.1	
popash	1	1.4	0.9	1.1	0.7
planer tree	1	0.5	1.8	1.1	1.0
water locust	2	0.3	1.1	0.7	1.9
possum haw	3	0.1	0.9	0.5	0.9
sycamore	3	0.5	0.4	0.4	0.9
green haw	2	0.4	0.3	0.4	0.1
box elder	3	0.4	0.1	0.3	0.6
laurel oak	4	0.1	0.5	0.3	
swamp cottonwood	1	0.5		0.3	0.8
swamp chestnut oak	3	0.3		0.2	
swamp privet	2	0.2	0.1	0.1	0.1
persimmon	3	0.1	0.03	0.1	0.3
swamp tupelo	1	0.1		0.1	
black tupelo	4	0.1		0.05	
buttonbush	1		0.001	0.001	0.3
sweetbay	3				0.1
red mulberry	3				0.1
stiffcornel dogwood	2				0.03
Total		100.0	100.0	100.0	100.0
Average total basal area, in m^2/ha		30.2	27.4	28.8	30.0
Number of canopy trees sampled		409	602	1,011	1,319
Total area sampled, in ha		na	1.31	na	2.55
Number of species		28	26	30	28

Appendix 6. (Continued) Relative basal area of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative basal area (rba) was weighted by the percent of area of each forest type in each reach. The sum of the rba of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; m^2/ha, square meters per hectare; na, not applicable]

Species	Floodplain species category	Relative basal area, in percent			
		1976 data			2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	
C. Swamp					
water tupelo	1	**46.3**	**52.7**	**49.8**	**48.3**
bald cypress	1	**22.0**	14.4	**17.9**	**18.9**
Ogeechee tupelo	1	14.8	17.1	16.1	16.1
popash	1	9.5	7.4	8.3	4.1
planer tree	1	3.0	2.8	2.9	2.4
swamp tupelo	1	1.3	1.8	1.5	1.0
overcup oak	2	1.0	1.0	1.0	2.8
swamp cottonwood	1	0.2	0.9	0.6	0.6
American elm	2	0.5	0.2	0.4	0.3
red maple	2	0.2	0.4	0.3	1.1
water hickory	2	0.4	0.2	0.3	1.0
green ash	2		0.4	0.2	0.8
river birch	2	0.01	0.3	0.2	0.6
swamp laurel oak	2	0.4		0.2	1.1
sycamore	3	0.04	0.2	0.1	0.04
black willow	1	0.2		0.1	
hackberry	3	0.04	0.1	0.1	0.1
water locust	2	0.04	0.1	0.1	0.6
swamp privet	2	0.04	0.04	0.04	0.01
buttonbush	1	0.04	0.005	0.02	0.02
slippery elm	4	0.04		0.02	
green haw	2		0.01	0.01	0.01
white titi	3		0.01	0.004	
winged elm	4		0.004	0.002	
sweetgum	3				0.10
possum haw	3				0.03
persimmon	3				0.01
ironwood	3				0.01
hazel alder	2				0.004
box elder	3				0.001
Total		100.0	100.0	100.0	100.0
Average total basal area, in m^2/ha		54.7	65.0	59.8	52.6
Number of canopy trees sampled		640	544	1,184	1,582
Total area sampled, in ha		na	0.72	na	2.45
Number of species		20	21	24	26

Appendix 7. Relative density of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative density (rd) was weighted by the percent of area of each forest type in each reach. The sum of the rd of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable, trees/ha, trees per hectare]

Species	Floodplain species category	Relative density, in percent				
		Canopy tress				Subcanopy trees
		1976 data				
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data	2004 data	2004 data
A. High bottomland hardwoods						
ironwood	3	**25.6**	6.1	**22.4**	**12.2**	7.4
sweetgum	3	**17.5**	**36.4**	**20.2**	**19.8**	4.9
possum haw	3	**15.2**	**9.4**	**15.6**	4.3	**29.4**
hackberry	3	11.3	7.6	10.5	**13.1**	**19.2**
swamp privet	2	6.0	0.9	6.0		
box elder	3	3.4	5.3	3.9	8.5	5.0
swamp laurel oak	2	3.2	3.4	3.5	2.0	1.4
water oak	3	3.8	2.8	3.4	**8.9**	6.2
green ash	2	1.3	**8.0**	2.6	2.0	1.1
overcup oak	2	2.3	1.1	2.4	0.8	2.1
American elm	2	1.3	1.4	1.3	3.2	0.7
chinaberry	4	0.8	5.4	1.3	1.6	0.7
water hickory	2	1.0	3.8	1.3	2.1	1.1
sycamore	3	1.7	2.2	1.3	1.6	
red maple	2	1.4	0.9	1.2	0.8	0.9
green haw	2	0.8	2.1	0.7	0.3	1.1
swamp chestnut oak	3	0.7		0.7	0.9	1.1
red mulberry	3	0.7	0.3	0.4	0.7	0.3
winged elm	4	0.4	0.9	0.4	3.3	2.7
slippery elm	4	0.6		0.3	0.6	0.1
persimmon	3		1.0	0.2	1.2	2.5
swamp tupelo	1	0.3		0.2	1.2	
black walnut	4		0.9	0.1		
buckthorn bumelia	3	0.3		0.1	0.4	0.6
bald cypress	1	0.2		0.1		
black tupelo	4	0.1		0.04		
spruce pine	3	0.1		0.03		
pagoda oak	3	0.1		0.03		
river birch	2		0.1	0.02	0.6	
loblolly pine	4	0.03		0.01		
American holly	3				6.8	**8.6**
silverbell	4				1.7	1.1
bitternut hickory	3				0.1	1.7
southern magnolia	4				0.3	
popash	1				0.4	
planer tree	1				0.1	
Chinese tallow tree	3				0.1	
cherry laurel	4				0.1	0.2
Ogeechee tupelo	1				0.1	
elderberry	3					0.1
Total		100.0	100.0	100.0	100.0	100.1
Average total density , in trees/ha		687	545	702	564	467
Number of trees sampled		352	283	635	671	620
Total area sampled, in ha		na	0.49	na	1.22	1.22

Appendix 7. (Continued) Relative density of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative density (rd) was weighted by the percent of area of each forest type in each reach. The sum of the rd of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable, trees/ha, trees per hectare]

Species	Floodplain species category	Relative density, in percent				
		Canopy tress				Subcanopy trees
		1976 data			2004 data	2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data		
B. Low bottomland hardwoods						
swamp laurel oak	2	4.4	**15.0**	**9.9**	**6.8**	3.2
overcup oak	2	**12.3**	**6.5**	**9.3**	5.3	6.4
water hickory	2	6.3	**11.4**	**9.0**	**14.0**	4.6
ironwood	3	**8.8**	**8.9**	**8.8**	**6.7**	3.6
green ash	2	**11.1**	6.3	**8.6**	5.5	2.2
river birch	2	**14.8**	2.0	**8.2**	4.5	0.1
American elm	2	**9.2**	**6.9**	8.0	5.6	1.6
red maple	2	8.6	3.9	6.1	**8.0**	**9.0**
sweetgum	3	6.3	4.0	5.1	6.8	2.6
planer tree	1	1.3	**7.4**	4.5	3.5	3.9
possum haw	3	2.0	6.4	4.2	**7.4**	**42.7**
hackberry	3	3.1	3.3	3.2	**7.3**	7.7
bald cypress	1	0.4	5.0	2.8	2.3	0.6
Ogeechee tupelo	1	1.7	3.7	2.7	3.4	1.0
popash	1	1.4	1.5	1.4	1.6	1.2
water tupelo	1	1.8	0.9	1.3	2.5	0.2
green haw	2	1.1	1.4	1.3	0.7	1.8
swamp privet	2	1.7	0.6	1.1	0.6	2.2
sycamore	3	0.4	1.4	0.9	0.7	
black willow	1		1.6	0.8		
box elder	3	1.6	0.1	0.8	1.7	4.4
water locust	2	0.3	1.3	0.8	1.3	0.3
water oak	3	0.6	0.2	0.4	0.5	0.3
swamp cottonwood	1	0.4		0.2	0.3	
laurel oak	4	0.02	0.2	0.1		
persimmon	3	0.1	0.1	0.1	0.9	0.4
black tupelo	4	0.1		0.03		
swamp tupelo	1	0.05		0.02		
swamp chestnut oak	3	0.05		0.02		
buttonbush	1		0.02	0.01	1.4	0.5
stiffcornel dogwood	2				0.3	1.3
red mulberry	3				0.3	
sweetbay	3				0.1	
American holly	3					0.2
Total		100.0	100.0	100.0	100.0	100.00
Average total density , in trees/ha		459	497	478	528	420
Number of trees sampled		409	602	1,011	1,319	1,240
Total area sampled, in ha		na	1.31	na	2.55	2.55

Appendix 7. (Continued) Relative density of tree species in forests of the Apalachicola River floodplain, Florida.

[Relative density (rd) was weighted by the percent of area of each forest type in each reach. The sum of the rd of the most dominant species (**in bold**) is greater than 50 percent. Species are sorted by dominance in the combined 1976 data. Scientific names of species are listed in appendix 1. ARQA, Apalachicola River Quality Assessment; ha, hectare; na, not applicable, trees/ha, trees per hectare]

Species	Floodplain species category	Relative density, in percent				
		Canopy tress				Subcanopy trees
		1976 data			2004 data	2004 data
		ARQA cruise-transect data	Thesis and ARQA intensive-plot data	Combined 1976 data		
C. Swamp						
popash	1	**29.3**	**33.3**	**31.2**	**16.8**	**16.4**
water tupelo	1	**28.5**	**28.8**	**28.7**	**33.5**	3.9
Ogeechee tupelo	1	15.4	10.2	12.9	10.9	2.1
bald cypress	1	12.8	11.4	12.1	16.3	**17.5**
planer tree	1	10.2	9.7	9.9	8.1	**19.5**
swamp tupelo	1	0.6	1.3	0.9	0.9	0.0
red maple	2	0.3	1.0	0.7	3.1	6.9
river birch	2	0.4	0.8	0.6	2.0	2.0
swamp cottonwood	1	0.5	0.7	0.6	0.5	0.1
overcup oak	2	0.4	0.6	0.5	2.6	4.4
American elm	2	0.5	0.3	0.4	0.5	1.7
water hickory	2	0.1	0.5	0.3	0.7	2.7
sycamore	3		0.5	0.3	0.03	0.0
swamp privet	2	0.2	0.2	0.2	0.1	0.4
water locust	2	0.3	0.1	0.2	0.7	0.6
green ash	2		0.2	0.1	0.9	0.5
buttonbush	1	0.1	0.03	0.1	0.2	4.1
hackberry	3	0.04	0.1	0.1	0.1	0.5
black willow	1	0.1		0.1		
green haw	2		0.1	0.1	0.03	0.3
white titi	3		0.1	0.04		0.3
winged elm	4		0.05	0.02		0.1
slippery elm	4	0.04		0.02		
swamp laurel oak	2	0.04		0.02	1.0	1.1
sweetgum	3				0.3	0.1
possum haw	3				0.3	1.9
persimmon	3				0.2	0.4
hazel alder	2				0.1	4.7
ironwood	3				0.1	0.2
box elder	3				0.01	0.6
American snowbell	2					5.4
stiffcornel dogwood	2					1.5
winterberry	2					0.1
sarvis holly	1					0.1
Total		100.0	100.0	100.0	100.0	100.0
Average total density , in trees/ha		1082	1016	1049	670	286
Number of trees sampled		640	544	1,184	1,582	651
Total area sampled, in ha		na	0.72	na	2.45	2.45

Appendix 8. Average Floodplain Indices of plots where tree species were sampled in 1976 forests of the Apalachicola River floodplain, Florida.

[Species are arranged in descending order by average Floodplain Index (FI) of the plots where they were sampled in 1976. Species with a sample size of less than 5 trees are not included. Scientific names of species and their Floodplain Species Categories are listed in appendix 1]

Species	Floodplain species category	Number of trees sampled	Average FI of plots where sampled
chinaberry	4	8	3.063
red mulberry	3	7	2.853
water oak	3	50	2.730
swamp chestnut oak	3	9	2.706
sweetgum	3	299	2.614
box elder	3	22	2.571
hackberry	3	148	2.547
ironwood	3	110	2.528
possum haw	3	77	2.505
sycamore	3	37	2.439
winged elm	4	11	2.429 [a]
persimmon	3	6	2.367
green ash	2	134	2.281
green haw	2	28	2.250
swamp laurel oak	2	138	2.249
American elm	2	110	2.209
water hickory	2	174	2.154
red maple	2	54	2.061
overcup oak	2	136	1.980
river birch	2	31	1.848
swamp privet	2	12	1.842
water locust	2	12	1.750
swamp cottonwood	1	17	1.461
black willow	1	12	1.384
planer tree	1	102	1.298
swamp tupelo	1	26	1.279
popash	1	195	1.254
Ogeechee tupelo	1	162	1.226
bald cypress	1	246	1.190
water tupelo	1	440	1.138
Total		2,830	

[a] One winged elm sampled in a swamp plot may have been misidentified. Average FI without this plot is 2.770.

Appendix 9. Changes in Floodplain Indices from 1976 to 2004 for individual replicate plots in forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. Prefix of plot name indicates transect name. FIs are calculated from relative basal areas of canopy trees weighted by the Floodplain Species Category (FSC). Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n, sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

(orange shading)	Indicates FI for 2004 plot is drier than FI for 1976 plot (difference is positive)
(blue shading)	Indicates FI for 2004 plot is wetter than FI for 1976 plot (difference is negative)

Forest type	Plot name	Floodplain Index (FI)		Difference in FI (2004 canopy minus 1976 canopy)
		1976 canopy	2004 canopy	
A. Upper Reach				
Hiblh	CH-01	3.000	3.029	0.029
	CH-02	3.000	3.258	0.258
	TO-09	3.000	3.056	0.056
	SE-IP4	3.047	2.809	-0.238
	SE-IP6	2.516	2.754	0.238
	SE-22	2.750	2.342	-0.408
	SE-23	2.750	2.729	-0.021
	SE-25	2.500	2.581	0.081
	BLT-L	2.650	2.830	0.180
Loblh	TO-04	2.000	2.727	0.727
	TO-06	2.273	2.549	0.276
	TO-07	2.000	2.143	0.143
	SE-IP3	2.085	1.190	-0.895
	BLT-MS	2.228	2.092	-0.136
	BLT-MP	2.335	2.435	0.100
	BLT-BP	2.128	2.146	0.018
Swamp	TO-01	1.000	2.012	1.012
	TO-02	1.000	1.022	0.022
	TO-03	1.000	1.001	0.001
	SE-IP1	1.002	1.001	-0.001
	SE-IP2	1.000	1.001	0.001
	SE-06	1.400	1.482	0.082
	SE-12	1.000	1.000	0.000
	SE-13	1.000	1.000	0.000
	SE-14	1.000	1.002	0.002
	SE-15	1.000	1.000	0.000
	SE-16	1.000	1.001	0.001
	SE-17	1.000	1.003	0.003
	SE-18	1.000	1.007	0.007
	BLT-BS	1.077	1.048	-0.029
Average difference in FI for upper reach (n = 30)				**0.050 ***

Appendix 9. (Continued) Changes in Floodplain Indices from 1976 to 2004 for individual replicate plots in forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. Prefix of plot name indicates transect name. FIs are calculated from relative basal areas of canopy trees weighted by the Floodplain Species Category (FSC). Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n, sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for 2004 plot is drier than FI for 1976 plot (difference is positive)
Indicates FI for 2004 plot is wetter than FI for 1976 plot (difference is negative)

Forest type	Plot name	Floodplain Index (FI) 1976 canopy	Floodplain Index (FI) 2004 canopy	Difference in FI (2004 canopy minus 1976 canopy)
B. Middle Reach				
Hiblh	OR-01	2.667	2.780	0.113
	OR-30	2.909	2.749	-0.160
	MR-01	2.833	2.654	-0.180
	MR-07	3.000	2.745	-0.255
	PL-15	2.750	2.987	0.237
	PL-16	2.667	2.882	0.215
Loblh	OR-5.5	2.000	2.419	0.419
	MR-08	2.000	1.996	-0.004
	MR-16	2.167	2.157	-0.009
	MR-16.5	2.083	1.939	-0.145
	PL-01	2.000	2.185	0.185
	PL-02	2.200	2.046	-0.154
	PL-03	1.667	1.384	-0.282
	PL-08	2.000	1.887	-0.113
	WEW-FS	1.767	1.933	0.165
	WEW-HL	1.914	2.062	0.148
	WEW-UB1	2.169	2.185	0.016
Swamp	OR-08	1.000	1.017	0.017
	OR-32.5	1.000	1.844	0.844
	MR-06	1.333	1.000	-0.333
	MR-05	1.000	1.000	0.000
	PL-04	1.000	1.237	0.237
	PL-05	1.125	1.073	-0.052
	PL-06	1.250	1.708	0.458
	PL-07	1.111	1.637	0.526
	PL-09	1.000	1.000	0.000
	PL-10	1.500	1.825	0.325
	PL-11	1.000	1.116	0.116
	PL-12	1.000	1.000	0.000
	PL-13	1.000	1.138	0.138
	PL-14	1.375	1.065	-0.310
	WEW-LB1	1.384	1.216	-0.168
	WEW-BS	1.134	1.224	0.090
Average difference in FI for middle reach (n = 33)				**0.063**

Appendix 9. (Continued) Changes in Floodplain Indices from 1976 to 2004 for individual replicate plots in forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward a drier forest type. Prefix of plot name indicates transect name. FIs are calculated from relative basal areas of canopy trees weighted by the Floodplain Species Category (FSC). Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n, sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for 2004 plot is drier than FI for 1976 plot (difference is positive)
Indicates FI for 2004 plot is wetter than FI for 1976 plot (difference is negative)

Forest type	Plot name	Floodplain Index (FI)		Difference in FI (2004 canopy minus 1976 canopy)
		1976 canopy	2004 canopy	
C. Lower Reach				
Loblh	BR-IP11	1.961	1.298	-0.662
	BR-IP14	2.029	2.034	0.006
Swamp	BR-18	1.083	1.000	-0.083
	BR-3	1.000	1.167	0.167
	BR-4	1.000	1.030	0.030
	BR-5	1.000	1.044	0.044
	BR-IP13	1.006	1.020	0.015
	BR-20	1.000	1.000	0.000
Average difference in FI for lower reach (n = 8)				**-0.061**
Average difference in FI for Hiblh all reaches (n = 15)				**0.010**
Average difference in FI for Loblh all reaches (n = 20)				**-0.010**
Average difference in FI for Swamp all reaches (n = 36)				**0.088 ****
Average difference in FI for all plots (n = 71)				**0.044 ***

Appendix 10. Differences in Floodplain Indices between 2004 canopy and subcanopy tree-size classes for individual plots in the forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward the next drier forest type. Prefix of plot name indicates transect name. FIs for canopy trees are calculated from relative basal areas. FIs for subcanopy trees are calculated from relative density. Canopy trees have diameter at breast height (dbh) ≥ 7.5 cm; large canopy trees, dbh ≥ 25 centimeter (cm); small canopy trees, dbh < 25 and ≥ 7.5 cm; and subcanopy trees, dbh < 7.5 and ≥ 2.5 cm. Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n = sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for given size class is drier than FI for canopy trees (difference is positive)
Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

Forest type	Plot name	2004 Floodplain Index (FI)				Difference in FI		
		Canopy	Large canopy	Small canopy	Subcanopy	Large canopy minus canopy	Small canopy minus canopy	Subcanopy minus canopy
A. Upper Reach								
Hiblh	CH-01	3.029	3.000	3.097	2.971	-0.029	0.068	-0.058
	CH-02	3.258	4.000	3.087	3.000	0.742	-0.171	-0.258
	CH-L2	3.167	3.134	3.246	3.200	-0.033	0.079	0.033
	TO-09	3.056	3.038	3.195	3.094	-0.018	0.139	0.038
	SE-IP04	2.809	2.434	3.141	3.205	-0.374	0.332	0.396
	SE-IP06	2.754	2.712	2.963	2.966	-0.042	0.209	0.211
	SE-22	2.342	2.297	2.726	3.000	-0.045	0.385	0.658
	SE-23	2.729	2.295	3.192	3.034	-0.434	0.464	0.305
	SE-25	2.581	2.504	2.969	3.000	-0.078	0.387	0.419
	BLT-L	2.808	2.788	2.938	2.712	-0.020	0.130	-0.097
Loblh	TO-04	2.727	2.650	3.000	2.931	-0.077	0.273	0.204
	TO-06	2.549	2.441	2.942	2.868	-0.108	0.393	0.320
	TO-07	2.143	2.082	2.626	3.000	-0.060	0.483	0.857
	SE-IP03	1.190	1.102	1.513	2.647	-0.088	0.322	1.457
	BLT-MP	2.435	2.394	2.642	2.743	-0.040	0.207	0.308
	BLT-BP	2.146	2.125	2.285	2.541	-0.021	0.139	0.395
	BLT-MS	2.092	2.070	2.314	2.185	-0.023	0.222	0.093
Swamp	TO-01	2.012	1.943	2.884	2.882	-0.068	0.873	0.871
	TO-02	1.022	1.000	1.359	1.000	-0.022	0.337	-0.022
	TO-03	1.001	1.000	1.027	1.000	-0.001	0.026	-0.001
	SE-IP01	1.001	1.000	1.006	1.643	-0.001	0.005	0.642
	SE-IP02	1.001	1.000	1.009	1.053	-0.001	0.008	0.052
	SE-06	1.482	1.482	1.483	1.833	0.000	0.001	0.351
	SE-12	1.000	1.000	1.000	1.333	0.000	0.000	0.333
	SE-13	1.000	1.000	1.000	1.600	0.000	0.000	0.600
	SE-14	1.002	1.000	1.006	1.320	-0.002	0.004	0.318
	SE-15	1.000	1.000	1.000	1.524	0.000	0.000	0.524
	SE-16	1.001	1.000	1.004	1.500	-0.001	0.002	0.499
	SE-17	1.003	1.000	1.013	1.640	-0.003	0.010	0.637
	SE-18	1.007	1.000	1.041	1.640	-0.007	0.034	0.633
	BLT-BS	1.048	1.046	1.068	1.500	-0.002	0.020	0.452
Average difference in FI for all upper reach plots (n = 31)						**-0.028 ****	**0.174 ****	**0.360 ****

Appendix 10. (Continued) Differences in Floodplain Indices between 2004 canopy and subcanopy tree-size classes for individual plots in the forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward the next drier forest type. Prefix of plot name indicates transect name. FIs for canopy trees are calculated from relative basal areas. FIs for subcanopy trees are calculated from relative density. Canopy trees have diameter at breast height (dbh) ≥ 7.5 cm; large canopy trees, dbh ≥ 25 centimeter (cm); small canopy trees, dbh < 25 and ≥ 7.5 cm; and subcanopy trees, dbh < 7.5 and ≥ 2.5 cm. Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n = sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

Indicates FI for given size class is drier than FI for canopy trees (difference is positive)

Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

Forest type	Plot name	2004 Floodplain Index (FI)				Difference in FI		
		Canopy	Large canopy	Small canopy	Subcanopy	Large canopy minus canopy	Small canopy minus canopy	Subcanopy minus canopy
B. Middle Reach								
Hiblh	OR-30	2.749	2.750	2.736	3.000	0.002	-0.013	0.251
	OR-01	2.780	2.748	3.093	2.833	-0.032	0.313	0.053
	MR-01	2.654	2.623	2.792	2.853	-0.031	0.138	0.199
	MR-07	2.745	2.682	2.865	2.935	-0.063	0.120	0.191
	PL-15	2.987	3.000	2.925	2.875	0.013	-0.062	-0.112
	PL-16	2.882	2.907	2.840	2.957	0.025	-0.042	0.075
Loblh	OR-5.5	2.419	2.337	2.611	2.833	-0.082	0.192	0.415
	MR-08	1.996	2.000	1.982	2.176	0.004	-0.014	0.180
	MR-16	2.157	2.133	2.298	2.455	-0.024	0.141	0.297
	MR-16.5	1.939	2.000	1.847	1.250	0.061	-0.092	-0.689
	PL-01	2.185	2.204	2.165	2.526	0.019	-0.020	0.341
	PL-02	2.046	2.000	2.443	2.960	-0.046	0.396	0.914
	PL-03	1.384	1.372	1.490	none	-0.013	0.105	
	PL-08	1.887	1.913	1.528	2.250	0.026	-0.359	0.363
	WEW-FS	1.933	2.044	1.607	2.446	0.111	-0.326	0.513
	WEW-HL	2.062	2.000	2.235	2.920	-0.062	0.174	0.858
	WEW-UBX	2.185	2.000	2.919	2.923	-0.185	0.734	0.738
Swamp	OR-32.5	1.844	1.861	1.699	1.000	0.017	-0.146	-0.844
	OR-08	1.017	1.000	1.277	1.000	-0.017	0.260	-0.017
	MR-05	1.000	1.000	1.000	1.250	0.000	0.000	0.250
	MR-06	1.000	1.000	1.000	1.000	0.000	0.000	0.000
	PL-04	1.237	1.222	1.546	1.000	-0.015	0.309	-0.237
	PL-05	1.073	1.078	1.000	none	0.004	-0.073	
	PL-06	1.708	1.750	1.455	none	0.042	-0.254	
	PL-07	1.637	1.589	2.063	3.000	-0.048	0.426	1.363
	PL-09	1.000	1.000	1.000	1.000	0.000	0.000	0.000
	PL-10	1.825	2.000	1.571	1.294	0.175	-0.254	-0.531
	PL-11	1.116	1.000	1.698	1.955	-0.116	0.582	0.839
	PL-12	1.000	1.000	1.000	1.000	0.000	0.000	0.000
	PL-13	1.138	1.142	1.000	none	0.004	-0.138	
	PL-14	1.065	1.000	1.877	1.167	-0.065	0.812	0.102
	WEW-LBX	1.216	1.115	1.804	1.789	-0.101	0.588	0.573
	WEW-BS	1.224	1.197	1.405	2.120	-0.027	0.181	0.896
	WEW-BSX	1.000	1.000	1.000	1.000	0.000	0.000	0.000
Average difference in FI for all middle reach plots (n = 34)						**-0.012**	**0.108 ***	**0.233 ****

Appendix 10. (Continued) Differences in Floodplain Indices between 2004 canopy and subcanopy tree-size classes for individual plots in the forests of the Apalachicola River floodplain, Florida.

[A change of + 0.01 in a Floodplain Index (FI) is a change of 1 percent of the species composition (as determined by dominance) toward the next drier forest type. Prefix of plot name indicates transect name. FIs for canopy trees are calculated from relative basal areas. FIs for subcanopy trees are calculated from relative density. Canopy trees have diameter at breast height (dbh) ≥ 7.5 cm; large canopy trees, dbh ≥ 25 centimeter (cm); small canopy trees, dbh < 25 and ≥ 7.5 cm; and subcanopy trees, dbh < 7.5 and ≥ 2.5 cm. Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Hiblh, high bottomland hardwoods; IP, intensive plot; Loblh, low bottomland hardwoods; n = sample size; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

(orange)	Indicates FI for given size class is drier than FI for canopy trees (difference is positive)
(blue)	Indicates FI for given size class is wetter than FI for canopy trees (difference is negative)

Forest type	Plot name	2004 Floodplain Index (FI)				Difference in FI		
		Canopy	Large canopy	Small canopy	Subcanopy	Large canopy minus canopy	Small canopy minus canopy	Subcanopy minus canopy
C. Lower Reach								
Hiblh	EA-02	2.547	2.505	2.710	3.000	-0.042	0.164	0.453
	EB-01	2.835	2.821	2.839	2.889	-0.014	0.005	0.054
	EB-08	2.545	2.561	2.391	2.750	0.015	-0.155	0.205
Loblh	EA-01	2.433	2.456	2.339	3.000	0.023	-0.094	0.567
	EA-03	2.056	2.039	2.189	2.583	-0.017	0.133	0.527
	EA-04	1.662	1.661	1.685	1.846	-0.001	0.023	0.184
	EA-05	2.189	2.095	2.447	2.476	-0.094	0.258	0.287
	EA-08	1.500	1.523	1.345	1.854	0.023	-0.155	0.354
	EB-02	2.274	2.204	2.790	2.211	-0.071	0.516	-0.064
	EB-03	1.920	1.902	1.960	2.241	-0.018	0.039	0.321
	EB-06	1.652	1.648	1.765	1.900	-0.004	0.114	0.248
	EB-07	2.572	2.660	2.444	2.761	0.088	-0.128	0.189
	EC-03	2.301	2.373	1.941	2.852	0.072	-0.360	0.551
	EC-04	2.379	2.197	2.646	2.941	-0.182	0.267	0.562
	EC-05	2.349	2.368	2.284	2.700	0.020	-0.065	0.351
	EC-06	1.972	1.948	2.092	2.563	-0.024	0.121	0.591
	EC-07	1.818	1.877	1.618	2.393	0.059	-0.200	0.575
	BR-IP11	1.298	1.262	1.484	1.850	-0.037	0.185	0.552
	BR-IP14	2.034	2.045	2.000	2.625	0.010	-0.035	0.591
Swamp	EA-06	1.446	1.484	1.073	1.917	0.039	-0.373	0.471
	EA-07	1.022	1.000	1.247	1.263	-0.022	0.225	0.242
	EB-04	1.021	1.000	1.110	1.188	-0.021	0.088	0.166
	EB-05	1.009	1.000	1.116	1.100	-0.009	0.107	0.091
	EC-10	1.274	1.267	1.295	1.583	-0.007	0.020	0.309
	BR-IP13	1.020	1.000	1.233	1.667	-0.020	0.213	0.646
	BR-03	1.167	1.178	1.118	1.375	0.011	-0.049	0.208
	BR-04	1.030	1.033	1.015	1.625	0.002	-0.015	0.595
	BR-05	1.044	1.051	1.000	1.333	0.007	-0.044	0.289
	BR-18	1.000	1.000	1.000	1.000	0.000	0.000	0.000
	BR-20	1.019	1.014	1.100	1.000	-0.005	0.081	-0.019
Average difference in FI for all lower reach plots (n = 30)						**-0.007**	**0.030**	**0.337 ****
Average difference in FI for Hiblh (n = 19)						**-0.024 ****	**0.131 ****	**0.159 ****
Average difference in FI for Loblh (n = 34)						**-0.022 ***	**0.106 ****	**0.423 ****
Average difference in FI for Swamp (n = 42)						**-0.007 ****	**0.092 ****	**0.289 ****
Average difference in FI for all plots (n = 95)						**-0.016 ****	**0.105 ****	**0.310 ****

Appendix 11. Statistical evaluation of correlations between Floodplain Indices of 1976 and 2004 tree-size classes and flood durations in forests of the Apalachicola River floodplain, Florida.

[Forest composition is based on Floodplain Index (FI) values for indicated groups. Flood duration is the average number of days of flooding in the growing season based on stage in the adjacent river channel without any adjustments for water retention in depressions or other factors affecting the relation between river stage and floodplain water levels. Canopy includes trees ≥ 7.5 centimeter (cm) diameter at breast height (dbh); small canopy trees are < 25 and ≥ 7.5 cm dbh; subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. FIs for canopy trees calculated from relative basal areas. FIs for subcanopy trees calculated from relative density. Statistics not calculated for groups with sample size ≤ 5. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; n, sample size; p, probability; r, Pearson correlation coefficient; >, greater than; ≥, greater than or equal to; <, less than; ≤, less than or equal to]

(orange)	Indicates correlation is highly significant (p ≤ 0.05)
(yellow)	Indicates correlation is less significant (p < 0.1 > 0.05)
(gray)	Indicates correlation is not significant (p ≥ 0.1)
*	Indicates correlation is positive

Forest type	Reach	Pearson r values, significance, and sample size correlations between FIs and flood duration for four forest groups			
		1976 canopy trees	2004 canopy trees	2004 small canopy trees	2004 subcanopy trees
Hiblh	UPPER	r = -0.430 p = 0.016, n = 31	r = -0.644 p = 0.044, n = 10	r = -0.598 p = 0.068, n = 10	r = -0.662 p = 0.037, n = 10
	MIDDLE	r = -0.483 p = 0.042, n = 18	r = -0.626 p = 0.184, n = 6	r = -0.502 p = 0.310, n = 6	r = -0.262 p = 0.616, n = 6
	LOWER	n = 0	n = 3	n = 3	n = 3
	All	r = -0.499 p = 0.0003, n = 49	r = -0.637 p = 0.003, n = 19	r = -0.628 p = 0.004, n = 19	r = -0.439 p = 0.060, n = 19
Loblh	UPPER	r = -0.031 p = 0.917, n = 14	r = -0.428 p = 0.338, n = 7	r = -0.587 p = 0.166, n = 7	r = -0.737 p = 0.059, n = 7
	MIDDLE	r = -0.394 p = 0.012, n = 40	r = -0.376 p = 0.254, n = 11	r = -0.449 p = 0.166, n = 11	r = -0.518 p = 0.125, n = 10
	LOWER	n = 3	r = -0.711 p = 0.002, n = 16	r = -0.504 p = 0.047, n = 16	r = -0.659 p = 0.006, n = 16
	All	r = -0.405 p = 0.002, n = 57	r = -0.563 p = 0.001, n = 34	r = -0.511 p = 0.002, n = 34	r = -0.603 p = 0.0002, n = 33
Swamp	UPPER	r = 0.410 * p = 0.038, n = 26	r = -0.012 p = 0.967, n = 14	r = -0.065 p = 0.825, n = 14	r = -0.033 p = 0.912, n = 14
	MIDDLE	r = -0.047 p = 0.814, n = 28	r = -0.095 p = 0.717, n = 17	r = -0.320 p = 0.2100, n = 17	r = 0.021 * p = 0.9431, n = 14
	LOWER	r = -0.327 p = 0.128, n = 23	r = -0.677 p = 0.022, n = 11	r = -0.426 p = 0.191, n = 11	r = -0.338 p = 0.310, n = 11
	All	r = -0.081 p = 0.485, n = 77	r = -0.108 p = 0.496, n = 42	r = -0.158 p = 0.317, n = 42	r = -0.163 p = 0.323, n = 39
Reaches	UPPER	r = -0.648 p < 0.0001, n = 71	r = -0.781 p < 0.001, n = 31	r = -0.731 p < 0.0001, n = 31	r = -0.669 p < 0.0001, n = 31
	MIDDLE	r = -0.702 p < 0.0001, n = 86	r = -0.757 p < 0.0001, n = 34	r = -0.763 p < 0.0004, n = 34	r = -0.649 p < .0001, n = 30
	LOWER	r = -0.785 p < 0.0001, n = 26	r = -0.841 p < 0.0001, n = 30	r = -0.841 p < 0.0001, n = 30	r = -0.776 p < 0.0001, n = 30
	ALL	r = -0.680 p < 0.0001, n = 183	r = -0.636 p < 0.0001, n = 95	r = -0.603 p < 0.0001, n = 95	r = -0.566 p < 0.0001, n = 91

Appendix 12. Statistical evaluation of differences between Floodplain Indices of 1976 and 2004 tree-size classes in forests of the Apalachicola River floodplain, Florida.

[Percentage of change in composition based on differences between Floodplain Index (FI) values for indicated groups. A change of + 0.01 in a FI is a change of 1% of the species composition (as determined by dominance) toward a drier forest type. Canopy includes trees ≥ 7.5 centimeter (cm) diameter at breast height (dbh); large canopy trees are ≥ 25 cm dbh; subcanopy trees are < 7.5 and ≥ 2.5 cm dbh. FIs for canopy trees calculated from relative basal areas. FIs for subcanopy trees calculated from relative density. Significant differences were determined using Wilcoxon matched-pairs signed-ranks test. Probabilities (p) shown with * are > 0.05 but < 0.10; with ** are ≤ 0.05. Statistics not calculated for groups with sample size ≤ 5. Hiblh, high bottomland hardwoods; Loblh, low bottomland hardwoods; >, greater than; n, sample size; ≥, greater than or equal to; <, less than; ≤, less than or equal to; %, percent]

(orange)	Indicates correlation is highly significant (p ≤ 0.05)
(yellow)	Indicates correlation is less significant (p < 0.1 > 0.05)
(gray)	Indicates correlation is not significant (p ≥ 0.1)

Forest type	Reach	Change in composition, statistical significance, and sample sizes		
		Pre-1954 to 1976 (change from 1976 large canopy to 1976 canopy trees)	From 1976 to 2004 (change from 1976 canopy to 2004 canopy trees)	From 2004 to 2085 [a] (change from 2004 canopy to 2004 subcanopy trees)
Hiblh	UPPER	4.0%, drier, n = 4	1.9% drier p = 0.496, n = 9	16.5% drier p = 0.160, n = 10
	MIDDLE	n = 0	0.5% wetter p = 1.000, n = 6	10.9% drier p = 0.156, n = 6
	LOWER	n = 0	n = 0	23.7% drier n = 3
	All	4.0% drier, n = 4	1.0% drier p = 0.720, n = 15	15.9% drier p = 0.012, n = 19
Loblh	UPPER	6.9% drier n = 4	3.3% drier p = 0.578, n = 7	51.9% drier p = 0.016, n = 7
	MIDDLE	0.9% wetter n = 3	2.1% drier p = 0.765, n = 11	39.3% drier p = 0.037, n = 10
	LOWER	6.5% drier n = 2	32.8% wetter n = 2	39.9% drier p = 0.001, n = 16
	All	4.2% drier p = 0.164, n = 9	1.0% wetter p = 0.729, n = 20	42.3% drier p < 0.001, n = 33
Swamp	UPPER	1.1% drier n = 4	7.9% drier p = 0.083, n = 14	42.1% drier p < 0.001, n = 14
	MIDDLE	no change n = 2	11.8% drier p ≤ 0.191, n = 16	17.1% drier p = 0.322, n = 14
	LOWER	0.3% drier n = 2	2.9% drier p = 0.438, n = 6	27.3% drier p = 0.004, n = 11
	All	0.6% drier p = 0.563, n = 8	8.8% drier p = 0.026, n = 36	28.9% drier p < 0.001, n = 39
Reaches	UPPER	4.0% drier p = 0.032, n = 12	5.0% drier p = 0.066, n = 30	36.0% drier p < 0.001, n = 31
	MIDDLE	0.6% wetter n = 5	6.3% drier p = 0.299, n = 33	23.3% drier p = 0.010, n = 33
	LOWER	3.4% drier n = 4	6.1% drier p = 0.813, n = 8	33.7% drier p < 0.001, n = 27
	All	2.8% drier p = 0.026, n = 21	4.4% drier p = 0.086, n = 71	31.0% drier p < 0.001, n = 91

[a] In 2085, the median age of surviving 2004 subcanopy trees will reach the median age (99 years) of the 2004 large canopy trees.