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LONG-TERM GROWTH TRENDS OF BALDCYPRESS (*TAXODIUM DISTICHUM* (L.) RICH.) AT CADDO LAKE, TEXAS

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Abstract: Caddo Lake, situated on the border of northeast Texas and northwest Louisiana, USA is a medium-sized lake dominated by stands of baldcypress (*Taxodium distichum*). A study of tree growth was initiated at Caddo Lake to address concerns about the health of the baldcypress ecosystem. The lake has been subjected to several dramatic water-level changes over the past 200 years, including water-level stabilization following dam construction in 1914. To assess the long-term growth trends of baldcypress trees and determine if a recent growth decline is occurring at Caddo Lake, increment cores were taken from 52 trees. The cores were crossdated and rings between the years 1900 and 1992 measured to the nearest 0.01 mm. Most cores were characterized by high variation in year-to-year growth. Although increasing growth rates were observed at most locations, trees from two backwater areas of the lake had recent growth rates lower than their long-term average. Growth amounts at these two sites were, however, within the historic range of variation. No recruitment was observed. From these data, we can conclude that the historic, extreme changes in hydrologic regime and the current stabilized water levels have not resulted in an overall decline in baldcypress growth at Caddo Lake.

Key Words: baldcypress, dendroecology, flooding, herbivory, hydrologic regime, *Taxodium distichum*, Texas, tree growth trends, tree-ring analysis

INTRODUCTION

Caddo Lake is a picturesque body of water on Big Cypress Bayou, a tributary of the Red River, in northeast Texas and northwest Louisiana, USA. Many areas of the lake are characterized by dense stands of baldcypress (*Taxodium distichum* (L.) Rich.) growing along the shore and on numerous submerged islands. Although water levels have been maintained by a dam since 1914, Russ (1975) considered Caddo a natural lake because its original formation is believed to have been the result of a monumental logjam. A history of dramatic changes in the hydrologic regime during the past 200 years has shaped the character of the lake's ecosystem, but these changes have also contributed to growing concerns about tree health in the extensive baldcypress forest. Klimas (1987) suggested that continuation of the current stabilized hydrologic regime at Caddo Lake would result in extensive baldcypress mortality within 50 years.

Prior to about 1800, the Caddo Lake area was a mixture of bottomland hardwoods and swamp forest (Janes 1914) that was subjected to partial draining during dry years and flooding in wet years. Sometime during the late 1700s or early 1800s, a logjam on the Red River, called "the great raft," caused long-term flooding in the Caddo Lake area. Although the origin of the logjam is unknown, it probably formed as coarse woody material washed downstream and was caught in tight bends of the river. Over time, the logjam filled in with debris such as leaves and silt and became solid enough to traverse on horseback (US Army Corps of Engineers 1992). The raft itself was stationary but had an apparent upstream migration rate of about 1.6 km per year because of new material washing down river to its head and decomposition of debris at the downstream end. As migration of the raft continued upstream, it seems to have caused backwater flooding that eventually breached the natural levee of the Red River north of Shreveport, Louisiana. As water from the Red River flowed through the breach, the Sodo Lake complex formed. Formation of this lake complex, which included Caddo, Clear, Cross, Shifttail, and Soda Lakes, resulted in several dramatic alterations of the local landscape. The vast bottomland hardwood forest was destroyed, a new baldcypress forest developed along the shorelines, and extensive sedimentation occurred as water, heavily laden with sediment, flowed into the slack water environment of Caddo Lake. A U.S. Department of the Interior report (Janes 1914) concluded that the lake probably formed just prior to 1800, based on the presence of upright hardwood stumps in the lake bed and the age structure of trees along the lake shore. Based on tree species distribution patterns, Janes (1914) estimated that water levels in Caddo Lake averaged about 51.66 m NGVD (National Geodetic Vertical Datum) during the early 1800s, with mean low and high of 50.44 m and 52.76 m, respectively. William Darby's 1816 map of Louisiana was the first official document to show the existence of Caddo Lake.

The U.S. Army Corps of Engineers (USACE) removed the raft from the mouth of Twelve-Mile Bayou (the new outlet of Caddo Lake) in 1873 (US Army Corps of Engineers 1992). Although destruction of the raft drained portions of Clear, Shifttail, Soda and Cross Lakes, the breaks in the Red River levee combined with heavy sedimentation in the lower part of Caddo kept water levels in the lake high for many years. As the Red River distributaries gradually closed and sediments in the lake washed downstream over the next decade, water levels in Caddo Lake began to recede. During the early 1900s, portions of the lake bed began to appear as dry land. Consequently, much of the area was converted to agriculture and logged. By 1912, Caddo Lake was exceedingly shallow, and large areas were covered with less than 20 cm of water (Shira 1913). To restore navigation on Caddo Lake, the USACE constructed a dam across Twelve Mile Bayou in 1914. The dam raised water levels in the lake by about 1.2 m. Between 1971 and 1990, Caddo Lake water levels have averaged 51.6 m NGVD, with mean lows and highs of 51.2 and 52.4 m (USACE 1992). Currently, the lake drains a basin of approximately 7,000 square km and has a surface area of 10,850 ha when water levels are at the spillway elevation of 51.4 m.

Major changes in hydrologic regime affect the survival and growth of many tree species throughout the southeastern United States. Both an increase (Penfound 1949, Eggler and Moore 1961, Mitsch et al. 1979, Harms et al. 1980, Stahle et al. 1992) or decrease (Reiley and Johnson 1982, Keeland and Sharitz 1995) in flood frequency or depth can affect tree growth. Penfound (1949) reported high mortality of buttonbush (*Cephalanthus occidentalis* L.), water tupelo (*Nyssa aquatica* L.), water elm (*Planera aquatica* (Walt.) Gmel.), and all other bottomland and upland tree species following permanent flooding caused by dam construction across Chicot Bayou in central Louisiana. Although initial survival of baldcypress was high even for seedlings protruding only a few centimeters above the water surface, survival of mature trees was reduced to 50% after 18 years of flooding. Radial growth of surviving trees, however, had increased slightly (Eggler and Moore 1961). Broadfoot and Williston (1973) also reported increased growth with greater flooding. In their study, flood years produced 50 to 100% greater growth than was observed in nonflood years. Growth of nearby nonflooded trees was also increased as the water table was raised to within the rooting zone.

In contrast, Mitsch et al. (1979) reported reduced growth of baldcypress subjected to long-term flooding caused by a beaver dam in southern Illinois. This apparent conflict in results may be partially explained by differences in the methods used in each study. Short-term growth measurements may give different results depending on the amount of time elapsed since the change in hydrologic regime. For example, Reelfoot Lake in Tennessee was created by the New Madrid earthquakes of 1811–1812, which flooded a vast area of swamp and bottomland hardwood forest. Stahle et al. (1992) developed a long-term growth chronology for surviving baldcypress trees in the lake and observed a growth response that varied through time. A very large growth surge was observed within three years of the earthquake, but this growth surge was followed by 30 years of depressed growth (Stahle et al. 1992). Growth amounts resembling pre-flood levels returned after 30 years. In a study of the effects of increased, semipermanent flooding in a South Carolina backwater swamp, Young et al. (1995) also reported a temporary increase in baldcypress radial growth that peaked in three years followed by at least 16 years of decreasing growth.

Reductions in flood frequency and depth have also been shown to impact annual growth. Johnson et al. (1976) and Reiley and Johnson (1982) reported reduced growth of box elder (*Acer negundo* L.), American elm (*Ulmus americana* L.), and green ash (*Fraxinus pennsylvanica* Marsh.) as a result of decreased periodic flooding below Garrison Dam in North Dakota. They attributed the decrease in growth to a net reduction in available soil moisture resulting from the attenuated flood regime. Keeland and Sharitz (1995) also reported reduced growth of baldcypress and water tupelo in response to drawdown associated with a summer drought in South Carolina. Although the summer drought reduced growth of all trees analyzed in that study, those trees subjected to lowered water levels were most affected.

Fears that the baldcypress ecosystem at Caddo Lake may be declining have been prompted by the 200-year history of major hydrologic regime changes. This study was initiatied to determine if a long-term decline in baldcypress growth was evident within the Texas portion of Caddo Lake, and if so, to determine if a significant relationship existed between declining growth and the hydrologic history of the lake. Our objectives were to examine the long-term growth of baldcypress trees at several locations on the lake and to compare Caddo Lake tree growth with growth of trees at a nearby site that was not subjected to the same dramatic water-level fluctuations.

Tree rings have been used extensively to examine possible growth declines because they provide the only source of long-term data on forest growth (Van Deusen et al. 1991). The information in tree-rings alone cannot be used to determine the cause of a decline, but these data are useful for discovering anomalous properties such as a growth decline (Cook and Zedaker 1992). Many studies have examined ring width (Phipps 1984, Johnson et al. 1988); however, LeBlanc (1990) suggested that ring volume and basal area increment may be more useful in detecting growth decline.

STUDY AREA

The study was conducted at five randomly located sites on the upstream or Texas portion of Caddo Lake (Figure 1). These included two backwater sites, Saw Mill Pond (SMP) and Pine Island Pond (PIP), a site located along a boat road through an old backwater area, Mossy Break (MBR), and two riverine sites located in old stream channels, Willowson Woodyard (WWY), and Goat Island (GIL; Table 1). Trees at all sites were subjected to essentially continuous flooding, with the exception of Saw Mill Pond, which was the only site that included unflooded baldcypress trees. A control site was established at Pruitt Lake, a nearby lake on a tributary of Big Cypress Bayou. This site was selected because it has not been subjected to the same water-level fluctuations or recent stabilization as Caddo Lake. Sample trees at all sites were randomly selected for analysis.

The swamp forest at all sites was dominated by baldcypress, a species that typically occurs in sites subjected to frequent and prolonged flooding up to 3 m or more in depth (Wilhite and Toliver 1990). Very few additional tree species occurred within or near the study plots as the transition from pure baldcypress stands to mixed hardwoods was rather abrupt (Klimas 1987).

Northeast Texas has a mild climate with cool winters and hot, humid summers. Mean January and July temperatures are 8.5°C and 28.4°C, respectively. Annual precipitation averages 113 mm and is evenly distributed throughout the year (National Oceanic and Atmospheric Administration 1994). Overall, water levels measured at the Caddo Lake dam (data from USACE, Vicksburg District) fluctuate between a maximum high of 53.8 m (observed in 1958) and low of 50.06 m (in 1934, Figure 2). Mean monthly water levels fluctuate over a much smaller range, with an average of 51.8 m in the spring and 51.2 m in the late summer and early fall (Figure 3). Except during years of severe drought, the majority of baldcypress stands at Caddo Lake experience flooding throughout the year.

METHODS

Increment borers were used to extract two cores from each tree. Cores were taken at points above the buttress and placed in plastic straws for transport. In the laboratory, cores were air-dried, glued to mounting boards, and sanded. Crossdating ensured the correct assignment of calendar years to annual rings over the time period 1900–1992 [using the skeleton plot method (Stokes and Smiley 1968, Fritts 1976)], and annual increments were measured to the nearest 0.01mm using a Henson measuring stage. Approximate ages for trees older than 92 years were determined by counting rings for the pre-1900 time period. No adjustments were made to estimate the time required for the seedling to grow to coring height. Crossdating was verified using the computer program COFECHA (Holmes 1983). COFECHA removed low-frequency variance by fitting a cubic smoothing spline to each individual series, then removed year-to-year persistence by autoregressive modeling before log-transforming all series. These procedures attempt to emphasize the high-frequency variability that is required for accurate crossdating. A master chronology was compiled by averaging all series except the one to be tested. Cross-correlation analysis between the test series and the master chronology, at lags from −10 to +10, was then used to check dating accuracy and to test for missing, micro, and/or false rings. This procedure was repeated for each of the individual series.

To further ensure crossdating accuracy, the Caddo Lake chronologies were compared with a chronology from nearby Grassy Lake, Arkansas (Stahle et al. 1994). Caddo Lake chronologies used in this comparison were the standard chronologies developed using the computer program ARSTAN (Cook and Holmes 1984), the same program used to develop the Grassy Lake chronology. ARSTAN removed age-related growth trends by dividing every year of each series by the annual expected growth value derived from a curve (negative exponential, regression line, or cubic spline with controlled flexibility) fitted to the ring-width series (Cook 1985, 1987). This de-

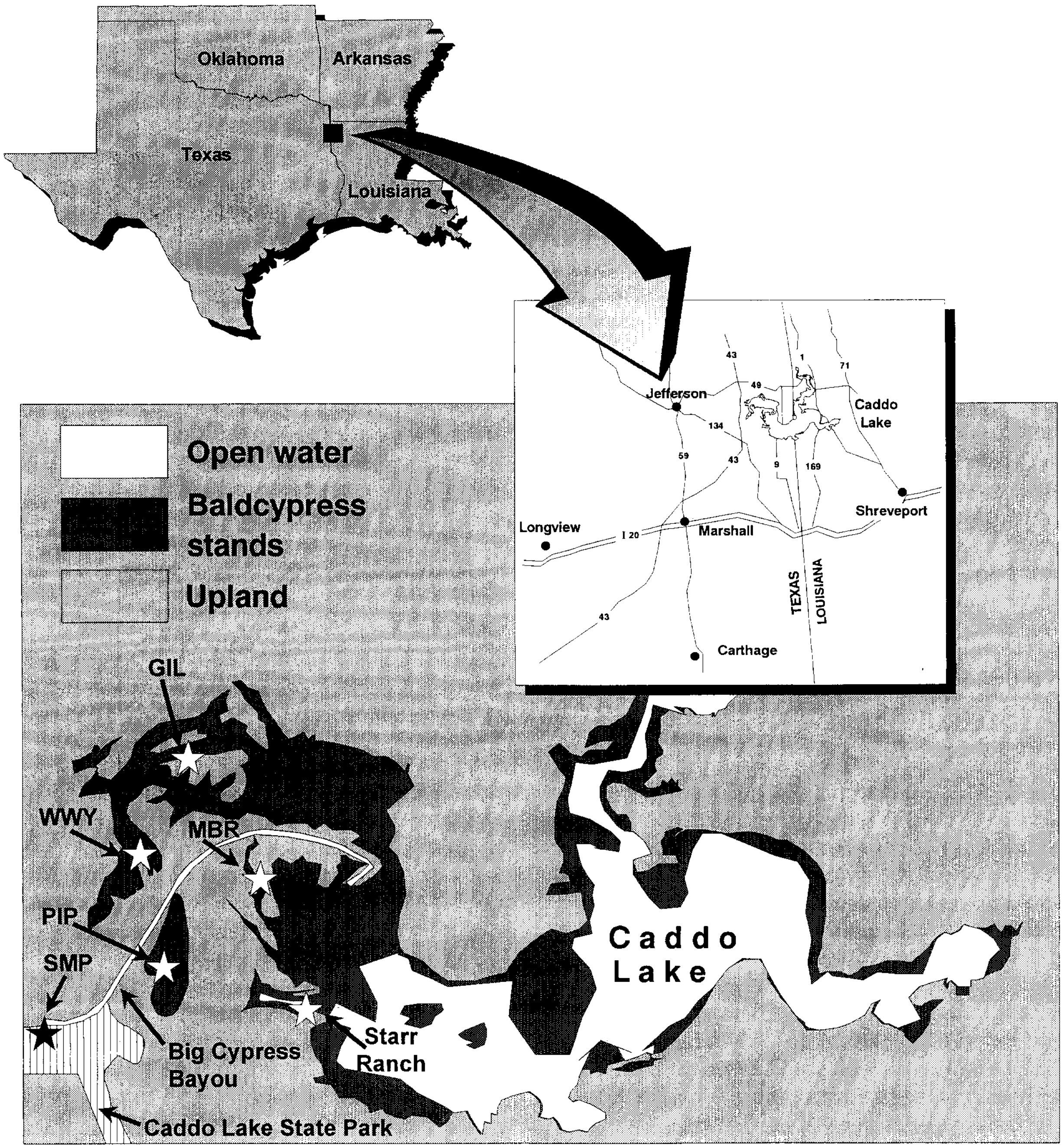

Figure 1. Location of study plots and Caddo Lake: GIL—Goat Island, MBR—Mossy Break, PIP—Pine Island Pond, SMP—Saw Mill Pond, and WWY—Willowson Woodyard. Starr Ranch is the location of a baldcypress artificial regeneration study.

trending procedure standardized the data to a mean of 1.0, producing dimensionless ring-width indices with no bias caused by differing growth rates among individual trees.

Additional analyses consisted of creating another series of chronologies for growth trend analysis. These chronologies were developed by converting each time series of radial increments to basal area increments, standardizing each series to a dimensionless index with mean of 0.0 and variance of 1.0, then averaging all series from each site to produce a time series of standardized mean annual basal area increments. Standardizing each time series was considered valid because growth trends rather than absolute amounts of growth were of interest. Detrending was not conducted for this analysis because it might have removed long-term trend data that were of interest in this study. The standardized time series for each site was then examined for a sustained growth decline and a decrease in annual growth variation that may indicate a reduced ability of

Table 1. Caddo Lake study plots with number of trees cored, number with heart rot, and estimated tree ages.

Site	Trees Cored	Heart Rot	Mean Age[a]	Max Age[b]
Saw Mill Pond (SMP)	6	2	206	355
Willowson Woodyard (WWY)	7	1	311	376
Goat Island (GIL)	12	2	62 (244)	244
Mossy Break (MBR)	7	2	88 (202)	246
Pine Island Pond (PIP)	11	4	86 (270)	279
Pruitt Lake (PRL)	9	7	215	329

[a] Tree age estimates based on counting of pre-1900 rings. Mean ages are considered conservative because they are based on an average of all cores without heart rot. Numbers in parentheses indicate trees from a distinctly different age group.
[b] Maximum ages are based on the innermost ring of each core and do not account for missed pith or the amount of time required for the tree to grow to core height.

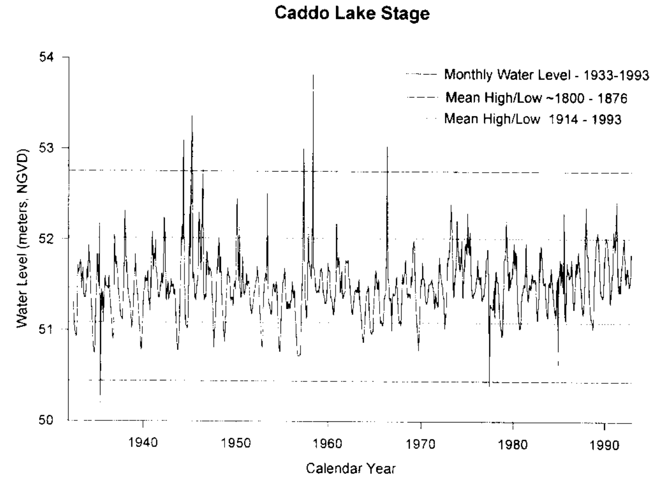

Figure 2. Monthly water levels at the Caddo Lake dam from 1933 to 1993. Mean high/low water levels for the period 1800–1876 were estimated by Janes (1914). Annual mean high/low water levels for 1914–1993 were determined from the monthly water-level data shown in this figure (these values do not necessarily agree with the U.S. Army Corps of Engineers calculations given in the text due to differences in the time period covered and the method of calculation).

the tree to respond to favorable environmental conditions (Jenkins and Pallardy 1995).

Time-series, cross-sectional regression analysis (TSCS; SAS Institute 1993) was used to test for differences among locations on Caddo Lake and for differences between Caddo Lake and Pruitt Lake trees. This procedure used a first-order autoregressive error structure with contemporaneous correlation between individual time series (Park's method) to test for significant differences in the long-term growth trends among sites. Parameter estimates were calculated via generalized least squares. Time series of standardized basal area increments (representing individual tree cores) were used in this analysis to test for differences among study sites in the regression slope (time trend) and any change in regression slope through time.

RESULTS AND DISCUSSION

Stand Characteristics

Fifty-two trees from six sites were sampled between April 1993 and August 1994 (Table 1). Several distinct cohorts of trees were observed at the various sites and across Caddo Lake (see also Janes 1914, Klimas 1987); however, heart rot made age estimation impossible for many trees (Table 1).

The youngest stand was located at Goat Island (Figure 1), where the majority of trees averaged 62 yrs in age. Establishment of these trees during the later 1920s, well after dam construction reflooded the lake in 1914, may have been related to drought as seen in the narrow rings of the older trees. Current water depths at these trees was about 0.6 m. A few scattered individuals were as old as 240 years, predating the original formation of Caddo Lake. Mixed-aged stands were also evident at Pine Island Pond (86 and 270 years) and Mossy Break (88 and 200 years). At Pine Island Pond, the younger trees were distributed along a strip near the shoreline, in water averaging 0.2 m deep. Apparently, the younger trees at this site germinated during the late 1890s while the lake was drained. Older trees were found further from shore in about 1.5 m of water. The Mossy Break study site was divided into two distinct areas by a boat road. A young stand (~88 years old) was located on the eastern half

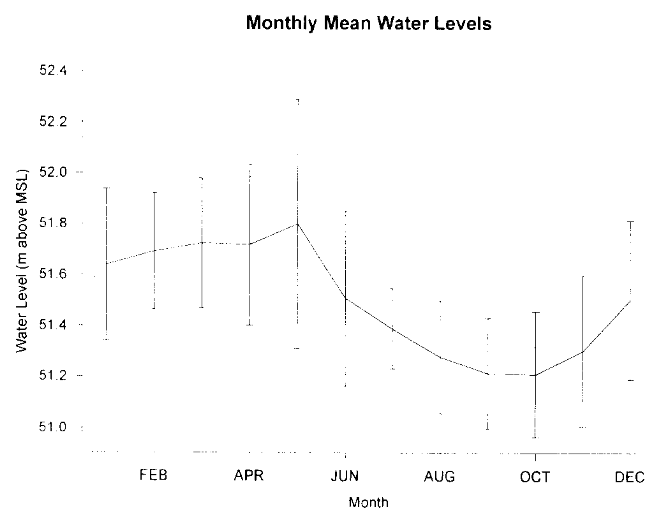

Figure 3. Seasonal variation of water levels based on monthly means at the Caddo Lake dam. Error bars represent one standard deviation.

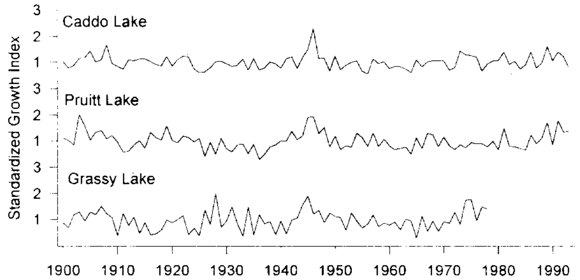

Figure 4. Tree-ring chronologies for Caddo Lake and Pruitt Lake in Texas and Grassy Lake in Arkansas. Chronologies were developed using program ARSTAN (see text).

of the site in about 0.5 m of water, and the older trees on the western half were in slightly deeper water of about 0.7 m.

Baldcypress stands at the other sites (Saw Mill Pond, Willowson Woodyard, and Pruitt Lake) appeared to be mixtures of several older cohorts, although cohort status was difficult to establish due to heart rot (Table 1). All trees sampled at Saw Mill Pond were in excess of 150 years. This included trees growing in about 1 m of water and other trees growing above the current shoreline. The Willowson Woodyard study plot consisted of trees in open water greater than 1 m in depth. All trees were in excess of 250 years old, and no younger trees were evident. Approximate tree ages were especially difficult to determine at the Pruitt Lake study plot due to the excessive proportion of hollow trees (80%). Of the two trees with pith or near pith evident on the cores, one was greater than 197 years old and the other was greater than 258 years in age.

Chronologies developed using ARSTAN (Cook and Holmes 1984) for Caddo Lake (all sites combined), Pruitt Lake, and Grassy Lake were generally in close agreement (Figure 4), with significant correlations for all three comparisons. The greatest similarity was between Caddo and Pruitt Lakes (r = 0.75, $P < 0.0001$). This was not unexpected as the two lakes are in close proximity and in the same watershed. Correlations between these two lakes and Grassy Lake in Arkansas were somewhat lower (Caddo Lake: r = 0.70, $P < 0.0001$; Pruitt Lake: r = 0.60, $P < 0.001$). These results indicate that the Caddo Lake chronologies were properly crossdated.

Growth Trend Analysis

Growth trends appeared fairly consistent among all Caddo Lake sites, including a mid-1940s growth surge that probably resulted from high rainfall and, at most sites, an increase in growth starting about 1970 (Figure 5). Overall, growth at all sites fell within the natural, historic variability for these trees. Long-term trends at three sites (Goat Island, Mossy Break, and Willowson Woodyard) and at Pruitt Lake showed below average growth for most of the 1900–1965 time period, followed by growth increases. Each of these sites, except for the Willowson Woodyard site, had significant time-squared TSCS regression coefficients (GIL: 0.0013, $P < 0.001$; MBR: 0.0004, $P < 0.033$; PRL: 0.0003, $P < 0.017$), indicating a trend of increasing growth. A similar trend at Willowson Woodyard was not significant. TSCS regression analysis also revealed similar growth patterns between all Caddo and Pruitt Lake tree-ring series; however the recent trend of increasing growth was greater at Pruitt Lake than for any of the Caddo Lake sites (Figure 5).

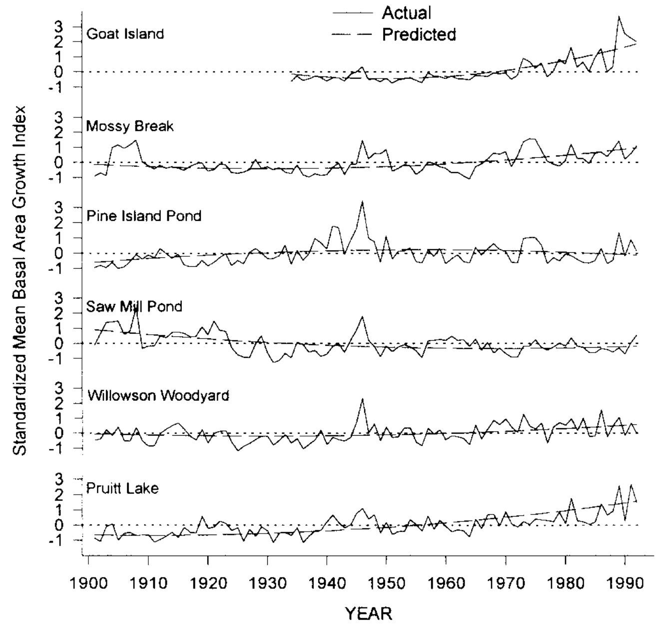

Figure 5. Tree-ring chronologies for the Caddo Lake and Pruitt Lake study sites. Dashed lines represent growth estimates from the time-series cross-section regression analysis, and dotted lines represents the long-term mean growth (standardized to zero) for each site.

In contrast to increasing growth trends at the other Caddo Lake sites, two sites (Pine Island Pond and Saw Mill Pond) had below average growth between about 1965 to 1992. The observed differences in growth trends may have resulted from the reduced mixing of water from Big Cypress Bayou at these backwater sites. Because these sites were isolated from the main flow of the bayou, they may be expected to have had lower levels of nutrients and dissolved oxygen.

Trees at Pine Island Pond appeared most different, with a time trend (slope) and change in slope significantly different from all other sites ($P < 0.01$; Table 2). An increasing growth trend from 1900 until about the mid- 1940s was followed by a decreasing growth

Table 2. Differences among sites for time and time-squared parameters as determined by time-series cross-sectional regression analysis. The time parameter represents the regression slope, and the time squared parameter represents a change in slope. Significant parameters indicate significant differences between sites in each pairwise comparison. A negative parameter indicates an increasing slope (or change in slope) at one site versus a decreasing slope at the other site.

		Parameter Estimates[a]					
Site[b]	Parameter	PIP	SMP	WWY	MBR	GIL	PRL
SMP	Time	−0.0623**					
	(Time)^2	0.0005**					
WWY	Time	−0.0368**	−0.0384**				
	(Time)^2	0.0004**	ns				
MBR	Time	−0.0719**	ns	ns			
	(Time)^2	0.0007**	ns	ns			
GIL	Time	−0.0560**	ns	ns	ns		
	(Time)^2	0.0007**	ns	0.0002*	ns		
PRL	Time	−0.0471**	ns	ns	ns	ns	
	(Time)^2	0.0006**	ns	ns	ns	ns	
Caddo	Time	x	x	x	x	x	ns
(All)	(Time)^2	x	x	x	x	x	0.0003**

[a] * or ** indicates that parameter estimates were significantly different at α = 0.05 or 0.01, respectively, and ns indicates the estimates were not significantly different. x indicates the parameters were not estimated.
[b] See text for description of study sites.

trend through 1992 (Figure 5). Although growth at Pine Island Pond appeared to be declining during the past several decades, neither the slope nor change in slope terms of the TSCS regression were significantly different from zero. In addition, average growth at this site from 1950 to 1992 was greater than from 1900 to about 1935. These observations suggest that although growth at this site is below average, the trees do not seem to be in a life-threatening decline. Only the trees at Saw Mill Pond appeared to be in what could be termed a growth decline, with a significant negative time trend over the past 92 years (−0.0380, $P <$ 0.019), below average growth during the past 30 years, and reduced annual variation in growth since the late 1940s (Figure 5).

Recruitment Patterns

A distinguishing feature of the sampled stands at Caddo Lake was an absence of saplings or small trees less than 60 to 90 years in age (see Klimas 1987). Although extensive regeneration has been observed each year (B. D. Keeland and S. L. King, unpublished data), very few seedlings survive. Factors thought to be most limiting to baldcypress recruitment include existing stand density, water-level control, and herbivory by beaver (*Castor canadensis* Kuhl), nutria (*Myocastor coypus* Molina), and swamp rabbits (*Sylvilagus aquaticus* Bachman).

CONCLUSIONS

The results of this study have not revealed evidence of a general long-term decline in baldcypress growth at Caddo Lake. In fact, most mature baldcypress trees have experienced greater growth during the past two decades as compared to the previous five decades. Examination of weather data from the Caddo Lake area provided no explanation for the recent (post 1960s) growth increase, and long-term water quality data are unavailable for comparison. Annual variation in water levels at Caddo Lake was reduced with the upstream construction of Lake of the Pines in 1958. It is unknown if this hydrologic alteration is related to the growth increase. Only two sites showed growth below the long-term mean, and growth at these sites appeared to be at a low, steady level, rather than in a continuing decline.

Logging operations probably passed over many of the older baldcypress trees because they were hollow. This implies that these trees have survived both drained and long-term flooded conditions as hollow trees for about 100 years. Wilhite and Toliver (1990) reported that baldcypress trees commonly live to be 400 to 600 years in age, with a few trees reaching 1,200 years. Stahle et al. (1988) discovered baldcypress trees in excess of 1,600 years in a North Carolina swamp. The relatively young age and apparently healthy and increasing growth of the baldcypress trees at Caddo Lake suggests that they will continue to survive and grow for many years.

The lack of seedling survival may become a concern at Caddo Lake in the future. The combined effects of an intact forest canopy providing deep shade, high water levels that submerge and drown young seedlings, and herbivory may be critical factors in the lack of baldcypress recruitment past the seedling stage over the past 60 years. At present, most areas of the lake support fully stocked baldcypress stands. The lack of recruitment could become a serious problem in the future, but probably not for many years.

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LITERATURE CITED

Broadfoot, W. M. and H. L. Williston. 1973. Flooding effects on southern forest. Journal of Forestry 71:584–587.

Cook, E. R. 1985. A time series analysis approach to tree-ring standardization. Ph.D. Dissertation. University of Arizona, Tucson, AZ, USA.

Cook, E. R. 1987. The decomposition of tree-ring series for environmental studies. Tree-Ring Bulletin 47:37–59.

Cook, E. R. and R. L. Holmes. 1984. Program ARSTAN and Users Manual. Lamont Doherty Geological Observatory, Palisades, NY, USA.

Cook, E. R. and S. M. Zedaker. 1992. The dendroecology of red spruce decline. p. 192–231. *In* C. Eagar and M. B. Adams (eds.) Ecology and Decline of Red Spruce in the Eastern United States. Springer-Verlag, New York, NY, USA.

Eggler, W. A. and W. G. Moore. 1961. The vegetation of Lake Chicot, Louisiana after eighteen years impoundment. Southwestern Naturalist 6:175–183.

Fritts, H. C. 1976. Tree Rings and Climate. Academic Press, New York, NY, USA.

Fritts, H. C. and T. W. Swetnam. 1989. Dendroecology: A tool for evaluating variations in past and present forest environments. Advances in Ecological Research 19:111–188.

Harms, W. R., H. T. Schreuder, D. D. Hook, C. L. Brown, and F. W. Shropshire. 1980. The effects of flooding on the swamp forest in Lake Ocklawaha, Florida. Ecology 61:1412–1421.

Holmes, R. L. 1983. Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bulletin 43:69–78.

Janes, L. L. 1914. Examination of Ferry Lake, Caddo Parish, Louisiana: An Ecologic Survey. Report to the Commissioner of the General Land Office, September 27, 1913.

Jenkins, M. A. and S. G. Pallardy. 1995. The influence of drought on red oak group species growth and mortality in the Missouri Ozarks. Canadian Journal of Forest Research 25:1119–1127.

Johnson, W. C., R. L. Burgess, and W. R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecological Monographs 46:59–84.

Johnson, A. H., E. R. Cook, and T. G. Siccama. 1988. Climate and red spruce growth and decline in the northern Appalachians. Proceedings of the National Academy of Sciences 85:5369–5373.

Keeland, B. D. and R. R. Sharitz. 1995. Seasonal growth patterns of *Nyssa sylvatica* var. *biflora, N. aquatica,* and *Taxodium distichum* as affected by hydrologic regime. Canadian Journal of Forest Research 25:1084–1096.

Klimas, C. V. 1987. Baldcypress response to increased water levels, Caddo Lake, Louisiana-Texas. Wetlands 7:25–37.

LeBlanc, D. C. 1990. Relationships between breast-height and whole-stem growth indices for red spruce on Whiteface Mountain, New York. Canadian Journal of Forest Research 20:1399–1407.

Mitsch, W. J., C. L. Dorge, and J. R. Wiemhoff. 1979. Ecosystem dynamics and a phosphorus budget of an alluvial cypress swamp in southern Illinois. Ecology 60:1116–1124.

National Oceanic and Atmospheric Administration. 1994. Climatological data annual summary; Louisiana, Vol. 99, No. 13. National Oceanic and Atmospheric Administration, Asheville, NC, USA.

Penfound, W. T. 1949. Vegetation of Lake Chicot, Louisiana in relation to wildlife resources. Proceedings of the Louisiana Academy of Science 12:47–56.

Phipps, R. L. 1984. Ring-width analysis. p. 225–271. *In* D. D. Davis (ed.) Air Pollution and the Productivity of the Forest. Izaak Walton League, Washington, DC, USA.

Reiley, P. W. and W. C. Johnson. 1982. The effects of altered hydrologic regime on tree growth along the Missouri River in North Dakota. Canadian Journal of Botany 60:2410–2423.

Russ, D. P. 1975. The quaternary geomorphology of the lower Red River valley, Louisiana. Ph.D. Dissertation, The Pennsylvania State University, State College, PA, USA.

SAS Institute. 1993. SAS/ETS User's Guide, Version 6, Second Edition, Cary, NC, USA.

Shira, A. F. 1913. The mussel fisheries of Caddo Lake and the Cypress and Sulphur Rivers of Texas and Louisiana. Bureau of Fisheries Economic Circular 6:1–10.

Stahle, D. W., M. K. Cleaveland, and J. G. Hehr. 1988. North Carolina climate changes reconstructed from tree rings: A.D. 372 to 1985. Science 240:1517–1519.

Stahle, D. W., R. B. VanArsdale, and M. K. Cleaveland. 1992. Tectonic signal in baldcypress trees at Reelfoot Lake, Tennessee. Seismological Research Letters 63:439–447.

Stahle, D. W., G. G. Hawks, and J. Langston. 1994. Tree-Ring Data, Grassy Lake, Arkansas. International Tree-Ring Data Bank, IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series AR039.CRN. NOAA/NGDC Paleoclimatology Program, Boulder, CO, USA.

Stokes, M. A. and T. L. Smiley. 1968. An Introduction to Tree-Ring Dating. University of Chicago Press, Chicago, IL, USA.

U.S. Army Corps of Engineers. 1992. Waterwise: The newsletter of the Shreveport to Daingerfield Study. Vols. 1–6. U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, MS, USA.

Van Deusen, P. C., G. A. Reams, and E. R. Cook. 1991. Possible red spruce decline: contributions of tree-ring analysis. Journal of Forestry 20:20–24.

Wilhite, L. P. and J. R. Toliver. 1990. *Taxodium distichum* (L.) Rich., Baldcypress. p. 563–572. *In* R. M. Burns and B. H. Honkala (technical coordinators) Silvics of North America: 1. Conifers. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC, USA.

Young, P. J., B. D. Keeland, and R. R. Sharitz. 1995. Growth response of baldcypress (*Taxodium distichum* (L.) Rich.) to an altered hydrologic regime. American Midland Naturalist 133:206–212.

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