Diameter Growth of Taxodium distichum (L.) Rich. and Nyssa aquatica L. from 1979–1985 in Four Louisiana Swamp Stands

W. H. CONNER
Baruch Forest Science Institute of Clemson University, Box 596, Georgetown, South Carolina 29442

AND

J. W. DAY, JR.
Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge 70803

ABSTRACT.—Annual diameter growth of baldcypress and water tupelo trees in four swamp stands in S central Louisiana were measured from 1979 to 1985. Seasonal patterns of growth were also monitored during 1979 and 1980 using vernier tree bands. Most growth occurred from late April to early July for both species, with baldcypress exhibiting the greatest growth in all sites. Trees of both species on the site with the least hydrological alteration, had the lowest growth rate. Trees in the crayfish pond (water level managed by pumping) and the impounded area (permanently flooded) had much higher growth rates than the control area. Annual defoliation by the forest tent caterpillar probably accounted for the low water tupelo growth rates compared to baldcypress. It is becoming more difficult to relate annual growth differences to hydroperiod alone in S Louisiana because of changes in tree growth and successional patterns due to increased waterlogging as a result of eustatic sea level rise and subsidence combined with insect herbivory and human manipulation of the environment.

INTRODUCTION

Before European settlement, the Mississippi deltaic plain was an area of constantly changing environmental conditions and shifting vegetational patterns. The Mississippi and Atchafalaya Rivers overflowed their banks, depositing a new layer of nutrient-rich silt with each flood. Open water areas would fill in with sediment and marsh plants would take root, further enhancing the rate of sediment deposition. As the land surface continued to rise as new sediments were deposited, swamp and bottomland hardwood tree species became established. When the rivers switched courses, the land building process continued in another part of the coastal plain while the abandoned delta would begin to erode and subside. Overall, however, channel switching created approximately 1.6 million ha of marshes and forested wetlands during the past 7000 yr (Cleveland et al., 1981).

The construction of flood protection levees has gradually confined the rivers and changed the natural hydrological functioning of the wetland system in Louisiana. Sediment-rich floodwaters no longer flow over the wetlands depositing silt to build up the land. Instead, storms rework and redistribute bay bottom sediments, but this is not enough to offset the natural rate of subsidence and sea level rise presently occurring (Baumann et al., 1984). In addition, canals, spoil banks, and highway embankments have altered natural runoff patterns. The result of these disruptions is that wetland areas are being inundated more frequently and to greater depths each year (Conner et al., 1981; Swenson and Turner, 1987). Although much attention has been focused on the loss of wetlands in Louisiana, most of the concern has been on marshes. Little attention has been focused on coastal forested
wetlands, although the flooding problem is just as severe and will have detrimental effects on these forests (Salinas et al., 1986; Conner and Day, 1988; Conner and Brody, 1989).

The intensity and duration of flooding are important factors controlling forest composition and growth (Bell, 1974; Bedinger, 1979; Mitsch and Rust, 1984), and few tree species are capable of surviving in a flooded environment. Baldcypress [Taxodium distichum (L.) Rich.] and water tupelo (Nyssa aquatica L.) are two common trees found in southeastern wetland forests, and they are capable of surviving and growing well under permanently flooded conditions (Carter et al., 1973; Brown et al., 1979; Brown, 1981; Conner et al., 1981; Mitsch and Rust, 1984). Extreme changes in hydrological patterns, however, can reduce growth or even cause death to these flood-tolerant trees (Hall and Smith, 1955; Broadfoot and Williston, 1973; Carter et al., 1973; Bell and Johnson, 1974; Harms et al., 1980; Conner et al., 1981; Lugo and Brown, 1984; Mitsch and Rust, 1984).

Most of the above-mentioned studies deal with tree growth and flooding in forests inundated after construction of reservoirs or by other flood control structures. In this situation, existing stands of trees are subjected to a sudden shock of continuous flooding. In lowland coastal areas of Louisiana, by contrast, wetland forests have typically become flooded gradually (Conner and Day, 1976; Conner et al., 1981; Slater, 1986) as a result of natural subsidence and rising sea level. Since most tree growth studies in Louisiana have focused on short-term data collection, the objective of this study was to monitor growth of selected trees for an extended period (1979–1985) under a variety of water level regimes to gain a better understanding of how these tree species respond to their changing environment.

STUDY AREA

The Barataria Basin swamp forest has been a major site for forested wetland studies in Louisiana. There are approximately 100,000 ha of forest in the basin with baldcypress and water tupelo being major components of the tree canopy (Conner and Sasser, 1985). The basin was once an overflow system of the Mississippi River but has been closed to overbank flow since the completion of the flood protection levees in the 1930s and 1940s. Soils are poorly drained clays formed by sediment deposition from the Mississippi River (Conner and Day, 1987).

Precipitation provides the majority of freshwater input to the basin (Conner and Day, 1987). Rainfall (mean annual = 160 cm) is fairly uniformly spread throughout the year, but the maximum usually occurs in July and the minimum in October. Annual totals varied from 92 to 219 cm during 1914–1978 (Sklar, 1983). Mean annual temperature is 20.6 C, and mean monthly temperature varies from 13 C in January to 27.5 C in July (Baumann, 1987).

The sites chosen for this study provided an excellent opportunity to investigate baldcypress and water tupelo growth in several areas with different hydrological regimes. A series of events leading to the creation of different flooding regimes is illustrated in Figure 1, which was compiled from aerial photographs. In 1952 the only known human artifact affecting the study area was Louisiana Highway 20 which was completed in 1931. The roadbed was constructed of material dredged from alongside the road, and it effectively eliminated any E-W overland flow. Flow from the western part of the basin was confined to Bayou Chevreuil.

By 1961, several changes had occurred. Bayou Chevreuil was dredged in 1956 in an attempt to alleviate flooding problems in the upper basin. Dredge material was placed on the N side of the bayou to a height of 1–2 m, preventing the natural exchange of water between the bayou and the swamp. In 1956–1957, a drainage canal was constructed along the southern edge of the agricultural fields. Dredge spoil was placed on the S side of the
Fig. 1.—Maps of the Barataria swamp showing development of the major hydrological alterations. Heavy black lines represent spoil banks resulting from dredge and fill operations.

canal, preventing any exchange between the fields and the swamp. With the completion of the drainage canal, a large section of swamp forest was bordered on the N, S and W by spoil banks. A small stream and natural levee on the eastern side of the area formed the fourth side of the enclosure.

In 1969 a gas well access road was constructed from Highway 20 across the northern part of the impoundment. The road embankment was extended from the access road to the drainage canal to create an impoundment for crayfish production (Study Site 1). This pond has operated for crayfish production since 1970, and water levels are manipulated to simulate the natural rise and fall of riverine swamp areas (flooded November–May, drained June–October) to enhance crayfish production. The rest of the impounded area (Study Site 2), however, has been flooded continuously since 1957 with up to 1 m of water (Conner et al., 1981).

Across Bayou Chevreuil from the impoundment is a relatively undisturbed baldcypress-water tupelo forest (Study Site 3). Water depth is controlled by water levels in the bayou. In low rainfall periods, the site slowly drains as water levels in the bayou drop below bank level. During high rainfall periods, bayou water flows over the banks and through the site.
Table 1.—Characteristics of banded trees and four forest stands in the Barataria swamp

<table>
<thead>
<tr>
<th>Site</th>
<th>Average diameter (cm ± 1 SD)</th>
<th>Average annual change in BA (cm² ± 1 SD)*</th>
<th>Total stand density (trees/ha)</th>
<th>Total stand basal area (m²/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cypress</td>
<td>Tupelo</td>
<td>Cypress</td>
<td>Tupelo</td>
</tr>
<tr>
<td>Crayfish pond</td>
<td>30.8 (3.9)</td>
<td>25.8 (4.9)</td>
<td>35.1 (7.4)</td>
<td>10.9 (1.7)</td>
</tr>
<tr>
<td>Impounded</td>
<td>33.8 (6.4)</td>
<td>25.3 (4.7)</td>
<td>24.5 (5.5)</td>
<td>13.0 (3.5)</td>
</tr>
<tr>
<td>Natural</td>
<td>33.9 (6.0)</td>
<td>30.8 (6.4)</td>
<td>17.2 (4.1)</td>
<td>4.9 (2.6)</td>
</tr>
<tr>
<td>Spoil break</td>
<td>27.1 (4.2)</td>
<td>27.6 (3.7)</td>
<td>21.3 (3.5)</td>
<td>12.1 (4.3)</td>
</tr>
</tbody>
</table>

* Average for entire 7-yr period

In July 1977, breaks were cut in the spoil bank along Bayou Chevreuil to create water circulation into and out of the impounded area. The forest adjacent to the breaks drained well, but the rest of the impounded area remained flooded. To take advantage of this situation, Study Site 4 was established in the forest drained by the spoil breaks.

METHODS

Water level was measured monthly at each site during 1979 and 1980 to characterize water level fluctuations in each site. Measurements were made at approximately 1 m from each banded tree (30 measurements/site/trip). Values from each site were averaged to provide a mean monthly water depth.

Aluminum vernier dendrometer bands (Liming, 1957) were installed on 15 randomly chosen baldcypress and 15 randomly chosen water tupelo at Sites 1–3 during 1977. Bands were installed at Site 4 in the spring of 1978 after all construction activities were completed and the spoil breaks were operational. Only dominant and codominant trees (based on crown position) were banded. No small or deformed trees were selected. Tree and stand characteristics for each area are given in Table 1. The bands were allowed to equilibrate for 1–2 growing seasons, and diameter measurements began at the end of 1978 and continued each winter until 1985. During 1979 and 1980, readings were made biweekly during the spring and summer monthly for the rest of the year. Band readings were made in the same order and at approximately the same time of day on each field trip to reduce the effects of diurnal diameter changes (Day and Monk, 1977). Diameter changes were converted to basal area (BA) increases (cm²/yr) to reduce the variability of growth increments among trees of different ages (Ewel and Parendes, 1984) and curves of cumulative average change in basal area (Winget and Kozlowski, 1965) were prepared for the 1979–1980 measurements. Analysis of variance (ANOVA) was used to determine whether growth rates differed during the study period among sites and between species.

RESULTS AND DISCUSSION

Swamp hydrology.—Average annual rainfall for the area is 170 cm. Rainfall during 1979 and 1980 was 170 cm and 202 cm, respectively. Even though water levels were only measured for 2 of the 7 yr of study, the measurements can be used as a general indication of water level fluctuations in the four areas (Conner and Day, 1976; Conner et al., 1981). Water levels in Site 1 were high in the autumn, winter and early spring and low during the summers due to the pumping regime used to enhance crayfish production (Fig. 2). Because the lease for management of the crayfish operation changed hands several times during this
study, maintenance of water levels, especially during the summer, was poor during 1979 and 1980, and the pond was not kept dry as much as in previous years. Site 2 was flooded continuously throughout the study. Water levels never dropped below 15 cm and averaged ca. 30 cm. The spoil breaks seemed to have no effect on the northern portion of the impounded area, indicating that there was probably some internal topographical relief preventing the flow of water. Site 3 experienced the most frequent and longest periods of dryness during the autumn and winter of 1979–1980 due to low water levels in Bayou Chevreuil. Normally, a short dry period occurs during late July–early August when rainfall is low and evapotranspiration is high (Conner et al., 1986). Site 4 did drain better due to the spoil breaks, but not as well as the natural area. In April 1980, water levels were generally the same for all sites as the result of nearly 80 cm of rainfall during the last 2 wk of March and the 1st 2 wk of April. Water levels dropped immediately after the stormy period and were low in Sites 1, 3 and 4 from July thru September.

Tree growth.—Growth curves based on monthly dendrometer readings for 1979–1980 are approximately logistic (Fig. 3), as observed by others (Day and Monk, 1977; Day, 1985). Diameter growth of baldcypress in all four sites began in late April–early May and ended by mid-July. Water tupelo diameter growth did not begin until late May–early June, but stopped at the same time as did the baldcypress. The late beginning of diameter growth by the water tupelo is probably related to the annual defoliation of these trees by the forest tent caterpillar (*Malacosoma disstria*). Each spring since the 1940s, water tupelo in southern Louisiana have been stripped of most or all their leaves by this caterpillar (Goyer, 1989). New leaves emerge in mid to late-May, and diameter growth begins soon thereafter.

During the 7-yr period of study, baldcypress consistently grew faster than water tupelo in every site (Figs. 3 and 4). Both species had greater growth in Sites 1, 2, and 4 than Site 3 in all but one instance (Site 2 cypress growth was less than Site 3 in 1983). Of all the
areas, Site 1 was the most productive for baldcypress (significant at 95% level, Fisher PLSD) for 6 of the 7 yr. The fluctuating water level regime of the crayfish pond was designed to mimic the natural riverine wetland ecosystem and probably enhanced baldcypress growth (Broadfoot and Williston, 1973; Mitsch and Ewel, 1979; Conner et al., 1981). Site 3, interestingly enough, had the lowest baldcypress growth. This site was chosen as a reference site because it was relatively undisturbed. Even though Site 3 has not been as extensively altered as the other sites in this study, it is undergoing rapid subsidence, and flooding during the growing season is common (Conner and Brody, 1989). Sites 2 and 4 were originally part of the same impoundment system until the breaks were placed along Bayou Chevreuil. The rate of BA growth of baldcypress was generally greater in Site 2 than in 4, although only significantly so in 1980 (95% level, Fisher protected LSD).

Baldcypress growth fluctuated from area to area and year to year with no definite pattern. Some sites had increased growth 1 yr while others declined or remained the same. Baldcypress growth peaked in Sites 1 and 2 in 1984 while it peaked in Sites 3 and 4 in 1983.

Basal area growth of water tupelo was generally much lower than baldcypress growth. Site 3 had the lowest growth for water tupelo, but Sites 2 and 4 were generally the areas of greatest BA growth for water tupelo followed by Site 1. Dicke and Toliver (1990) and Conner et al. (1981) also found that water tupelo grew slightly faster under continuously flooded conditions in Louisiana swamp forests. Except for slight variations, water tupelo had the more uniform growth patterns with all sites peaking in 1983 after which there was a steady decline through 1985.

Obviously, inundation regime differences do not wholly explain all the variation we observed in this study, and this illustrates the importance of longer term studies. In an earlier 1-yr study, Conner et al. (1981) concluded that hydrology was a major factor.
controlling productivity. Other factors that may have an influence on growth include light, stand density, insect herbivory, nutrient input, microtopographical variations and successional dynamics.

The measurements reported in Table 1 are for average stem growth of individual trees. When total stand productivity (mean growth per tree × stand density) is considered, then the ranking of sites is different. Site 2 is the least productive and Site 1 is the most productive (Conner et al., 1981). One of the primary factors leading to the high growth rate of individual trees at Site 2 is high light levels due to low tree density. The overall productivity of Site
3 is high even with a lower mean growth rate per tree because of the higher number of trees in the stand.

As mentioned above, the forest tent caterpillar is important in growth dynamics of water tupelo. Very few qualitative studies have been conducted in Louisiana on the severity of forest tent caterpillar defoliation although there has been an attempt to organize the existing data and point out research needs (Rejmanek et al., 1987). Forest tent caterpillar defoliations have occurred in the study area since the 1960s. Aerial surveys have been conducted annually since 1982 to determine the extent of the problem and areas are rated as to extent of damage (Richard Goyer, professor of Entomology, Louisiana State University, pers. comm.). The study area has been rated as moderately to heavily defoliated each year since surveys began. Water tupelos lose their leaves in August also. Goyer thinks the second defoliation is due to leaf damage received in the spring. A third set of leaves is not uncommon, and they last until frost. Energy expenditure to produce leaves may account for the slower water tupelo BA growth. A study in Alabama has shown that tupelo tress defoliated annually experience less growth (Morris, 1975). Morris also estimated equal losses in the forests of Louisiana.

Brown (1981) demonstrated that nutrient inflow was important in determining baldcypress growth rate. This helps explain the higher growth rate in Site 1 where floodwater is pumped from agricultural drainage canals. However, it does not explain the high growth rate in Site 2 where rainwater is the only source of water.

Day (1985) found that differences due to hydroperiod in the Dismal Swamp of Virginia could be masked by microtopographic variation within and among sites. In addition, he observed that stand age and successional dynamics also helped to explain site variations in this study. Stand age in the present study probably does not explain much of the variation. The entire area was logged during the early part of the century, and we assume that the present forest was established within a short time following that logging (Conner et al., 1981). Also, only dominant and co-dominant trees were selected for banding.

Microtopographical variation may be an important factor to consider in future studies. The study area has experienced many changes with logging, dredging, and mining activities. The attempt to reopen the impounded section of forest helps to illustrate how important it will be in future management plans to consider the whole system. Even though the idea of placing openings in the spoil bank may have been sound, the northern part of the impoundment still remains flooded. Small natural levees formed by streams that once flowed through the area and old railway lines from the earlier logging activity provide barriers to water flow, thus preventing it from completely draining as well as had been anticipated.

Successional dynamics were not considered when establishing this project, but some observations can be made from our experiences in the area. Local anthropogenic changes (canals, spoil banks, impoundments, etc.) have altered much of the area, and the present forest has developed in response to these activities. On a broader level, apparent water level rise (due to subsidence and sea level rise) and a lack of sedimentation also play an important role in determining the successional pathways that will determine the future forests (Conner and Brody, 1989).

Managing these forestlands is no longer a simple matter. Biological, hydrological, geological and climatological factors are all interacting to determine the environmental health of these forests. However, swamp forests in Louisiana cannot be left as is or they will continue to deteriorate as they are flooded for longer periods during the growing season because of natural subsidence (Conner and Day, 1988). Even though baldcypress and water tupelo are capable of surviving in a flooded environment (as evidence in the impounded site of this study), the total number of trees will decline through time as mortality occurs and no new trees enter the understory (Conner and Brody, 1989). Sound management plans
involving a multidisciplinary approach need to be developed now to save these forests for tomorrow.

Acknowledgments.—Research was supported by the Louisiana Sea Grant College Program, part of the National Sea Grant Program maintained by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Manuscript preparation was supported by the Department of Forest Resources, Clemson University. This work is dedicated to the memory of Harvey Rodriguez, Jr., who provided support and friendship to the authors.

Literature Cited


**Submitted 1 July 1991**

**Accepted 22 October 1991**