CYPRESS TREE-RING ANALYSIS IN RELATION TO WETLANDS AND HYDROLOGY

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ABSTRACT

In recent years, bald cypress, Taxodium distichum, has proved to be an extremely useful species in studies involving tree-ring analysis, wetlands, and hydrology. In this paper we illustrate the application of tree-ring analysis using bald cypress, to the resolution of a variety of ecological problems related to wetlands and hydrology. At Corkscrew Swamp Sanctuary, tree-ring analysis provided information on cypress forest structure and dynamics, and how they are related to substrate characteristics, water level fluctuations, site quality, and fire. We were also able to determine the most likely cause of saltwater intrusion into the Loxahatchee River estuary, where a severe dieback of the floodplain forest had occurred, and whether the area impacted had stabilized or was continuing to expand upstream. In another study at Corkscrew Swamp, we were able to assess sanctuary management practices involving water level manipulation. We found that year-round inundation adversely affects cypress growth. Cypress recovered quickly when an annual drydown was reestablished following a single year of continuous inundation, but recovery was slower following five years of continuous inundation.

INTRODUCTION

Bald cypress, Taxodium distichum, has proved to be an extremely useful species in studies involving tree-ring analysis. It has a very extensive range in the southeastern United States, and the closely related Montezuma cypress, T. mucronatum, is found from Texas into Central America. Within this area, it is one of the longest lived tree species. In addition, the environments where it occurs are conducive to the long term preservation of dead wood, either by submergence in water or burial by sediments.

Bald cypress is of particular value for hydrology and wetland studies because it is frequently the dominant or codominant canopy species in many forested wetlands (Duever et al. 1986, Ewel and Odum 1984). It also occurs along the periphery or as islands in many nonforested wetlands. Since wetlands are normally inundated for a significant portion of each year, factors which influence the growth of cypress are directly affected by the hydrologic regime and quality of the associated water.

In recent years, a number of researchers have successfully conducted tree-ring analyses with bald cypress using both ring counting (Duever et al. 1978, Brown 1984, Nessel et al. 1982) or dendrochronology (Bowers 1981, Stahle et al. 1985a, 1985b) techniques. The lag in development of this species' potential for tree-ring research has been due largely to the fact that ring boundaries in cypress are much more difficult to identify with certainty than they are for many species found in cooler or more arid climates. This is a function of the frequent occurrence of false and missing rings in trees at many sites, and the poor development of latewood in at least portions of cores from many older trees (Duever 1981).

Despite the difficulties involved in working with bald cypress, its usefulness for providing information on the ecology of cypress ecosystems (Brown 1984, Duever et al. 1976, Marois and Ewel 1983), and for documenting significant environmental impacts which can alter its growth rate (Duever et al, 1978, 1986, Nessel et al. 1982) has been demonstrated by a number of workers. Also, its value for the development of long term chronologies in the southeastern United States has been demonstrated (Stahle et al. 1985a), as has the feasibility of relating these chronologies to environmental parameters (Stahle et al. 1985b).

The objective of this paper is to illustrate the use of tree-ring analysis of bald cypress in the resolution of a variety of ecological problems related to wetlands and hydrology. Examples include the influence of hydrology on the characteristics and productivity of undisturbed freshwater forested wetlands, and the use of altered cypress growth rates to document the timing and significance of changes in water quality or water quantity. These examples represent only a few of the situations where tree-ring analysis of cypress has been a valuable tool in the resolution of important questions in our studies of wetland ecology and hydrology.

CYPRESS FOREST GRADIENTS

We had two hypotheses for why a dense stand of relatively small cypress trees occupies the outer edges of swamp forests in South Florida, and their size increases while their density decreases towards the forest interior (Figure 1). One was that size differences are controlled primarily by site "quality", and the other was that the larger trees are merely older. Tree-ring analysis allowed us to determine approximate ages of the cypress and whether there were differences in growth rates along the gradient from the forest edge to its center.

We tested our hypotheses using trees along the intensively studied Central Marsh Transect through the old growth cypress forest at Corkscrew Swamp Sanctuary in southwest Florida. Along this transect we measured diameter at breast height (dbh) and cored the four closest cypress at 30 m intervals from the outer edge of the forest to its center. We then determined approximate ages of the trees by making ring counts on the cores. There was a high correlation ($r = 0.915$, $n = 45$) between size and age of trees along the transect through the eastern half of the swamp forest

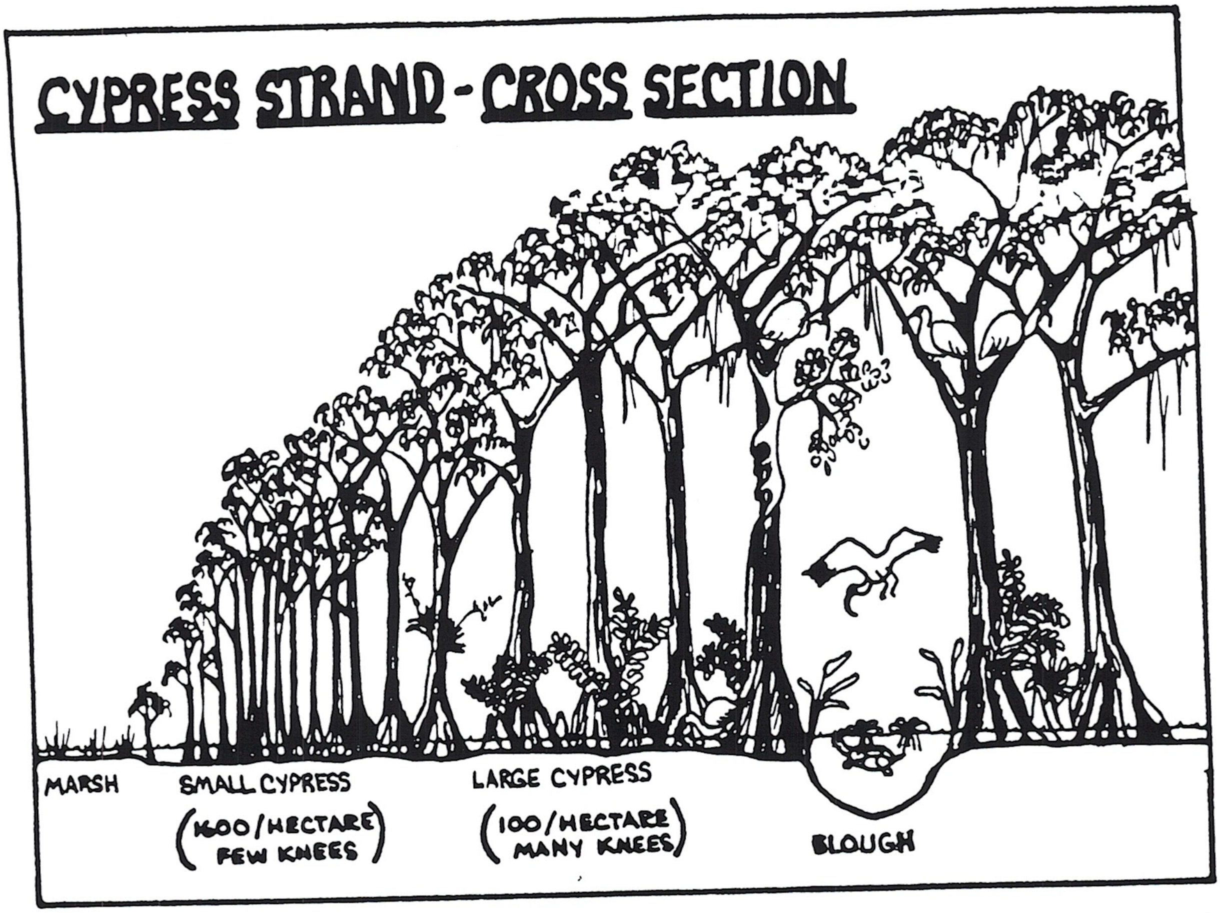


Figure 1. A schematic profile from the outside edge (left) to the center of a cypress swamp forest.

(Figure 2). Examination of a number of environmental parameters revealed no simple relationship between tree size and maximum wet season water levels, minimum dry season water levels, or surface topography. However, there was a high correlation (r = Ø.953, n = 18) between peat depth and dbh of the largest tree at each sampling point along the transect (Figure 3). A less detailed examination of these same parameters in the western part of the forest documented similar relationships there.

These correlations appear to be related to the annual duration of contact between the organic soil and the water table. In parts of the forest where the peat is deepest and is almost always in contact with the water table, the high capillary forces within the organic soils maintain relatively high moisture levels in the soils, litter, and vegetation, and a generally more moist microclimate within the forest. Particularly during the extended South Florida winter-spring dry season, a more moist environment would tend to reduce the frequency and severity of fires. This would in turn permit trees to persist for longer periods and attain greater ages and larger sizes.

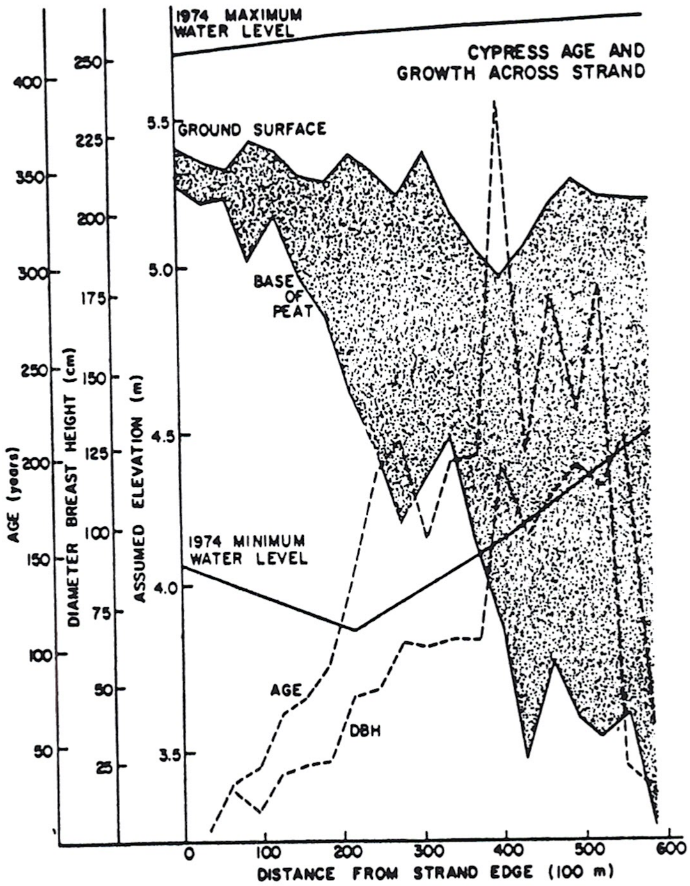


Figure 2. Cypress dbh and age in relation to substrates and water levels along the same section of the Corkscrew Swamp Central Marsh Transect shown in Figure 1 (Duever et al. 1986).

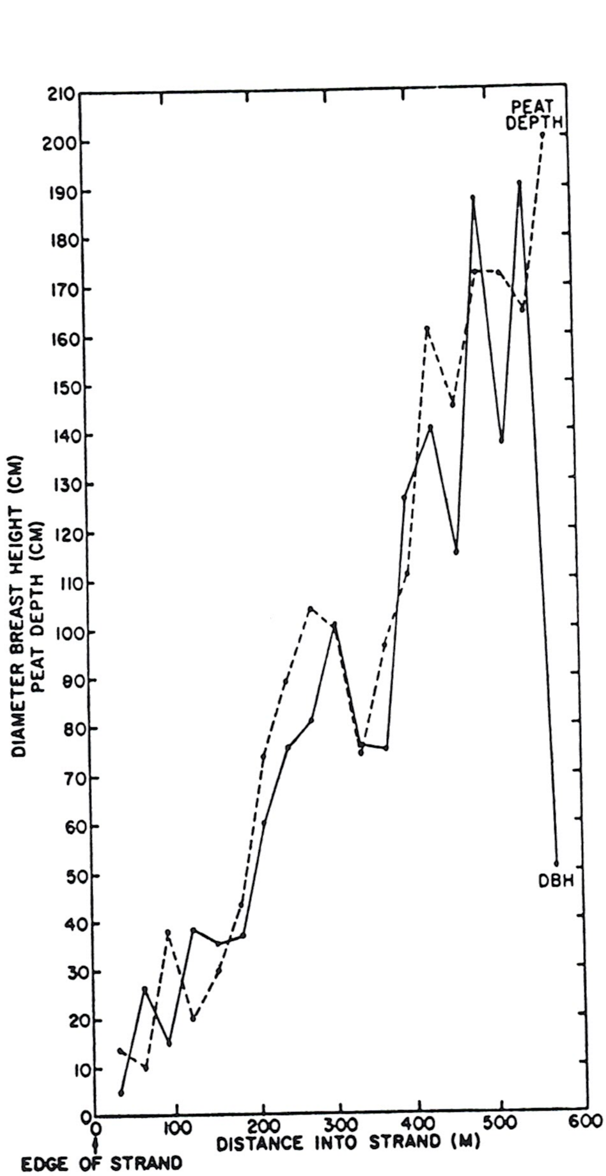


Figure 3. Peat depth and maximum cypress dbh along the same section of the Corkscrew Swamp Central Marsh Transect shown in Figure 1 (Duever et al. 1986).

As one moves toward the edge of the forest, the peat becomes more shallow and loses contact with the water table more frequently and for longer periods (Figure 2). Fires are therefore increasingly more frequent and severe toward the edges of the forest. Beyond its edge, where cypress could survive on the basis of hydrologic conditions, fire is so frequent that the young trees are killed before they become well enough established to survive even light fires.

Over the years, swamp forests probably expand and contract in response to the occurrence of fire, which is largely controlled by long term wet and dry cycles. During extreme droughts, even major forests are occasionally devastated by fire, but are reestablished during subsequent wetter periods. Evidence of occasional devastating fires is suggested by C-14 dates for a layer of peat overlying an ash layer at the bottom of one of the deeper sloughs within the cypress forest. This peat layer began to accumulate approximately 540 years B.P. On the basis of ring counts of tree cores, we determined a maximum age of approximately 500 years for cypress from this same forest at Corkscrew Swamp.

Light fires are more frequent. Even in the undisturbed old growth forest at Corkscrew Swamp, we found ample evidence (in the form of charcoal) of fires throughout the 5000 year old peat profile as well as on surface materials which indicated the occurrence of fires probably within the last 50 years. Light burning generally has little effect on cypress trees, but it reduces the dominance of hardwoods in these forests and may eventually eliminate them (Ewel and Mitsch 1978).

In order to further evaluate the possible influence of site quality on cypress growth rates across a strand, we examined annual ring width data from the Central Marsh Transect cypress cores. Two distinct patterns were apparent. During the first 50 years of their lives, trees nearer the forest center grew about 50% faster, while ring widths produced by trees over 150 years old were similar in all parts of the forest (Figure 4). Thus, site quality does appear to be better toward the center of a forest, but only younger trees seem able to take advantage of the more favorable conditions there. Trees with maximum early growth rates in excess of 5 mm/yr were relatively isolated individuals growing either in marsh habitats beyond the forest edge or in open sites adjacent to sloughs within the forest.

GROWTH RATES OF CYPRESS

Another application of tree-ring analysis to understanding cypress ecology involved looking at relative growth rates on different types of sites. When we plotted dbh against age for all of the available data on cypress at Corkscrew Swamp Sanctuary, we found that there was a fairly consistent relationship (Figure 5). The few exceptions were characteristically trees growing on unusual or disturbed sites.

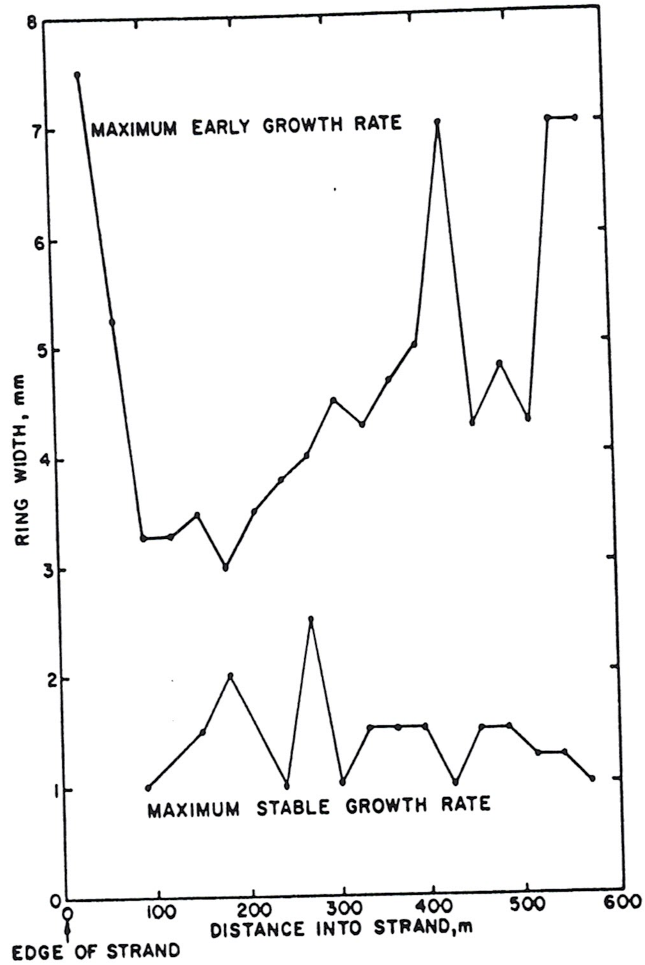
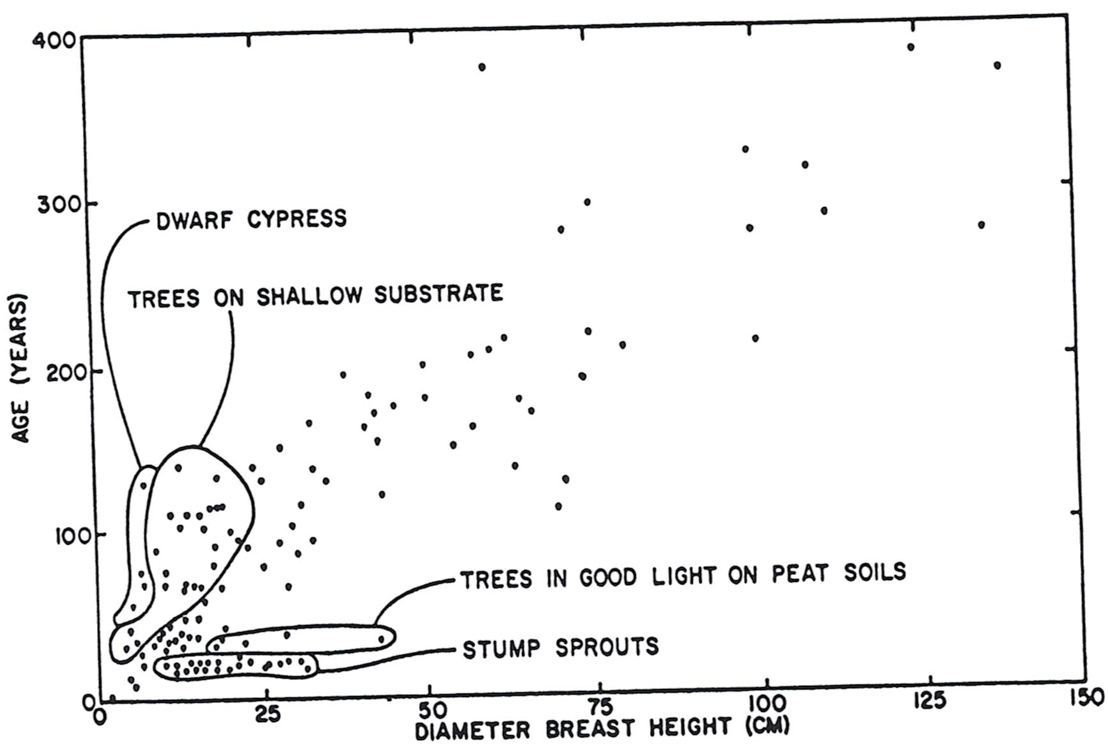


Figure 4. (Left) Cypress growth rates along the same section of the Corkscrew Swamp Central Marsh Transect shown in Figure 1 (Duever et al. 1986). Maximum early growth rate represents the generally widest rings observed during the first 50 years of a tree's life, and the maximum stable growth rate represents the generally widest rings observed after a tree is about 150 years old.

Figure 5. (Below) Correlation between cypress age and dbh at Corkscrew Swamp (Duever et al. 1986).



Trees growing in marl (calcitic clay) soils or in areas where rock is near the ground surface were generally small for their ages. This was most dramatic in the bonsai-like dwarf or scrub cypress with their enlarged buttressed bases and small boles and crowns. Their rings are almost always narrow, frequently with only 1 or 2 rows of cells each in the earlywood and latewood. Sites occupied by this cypress growth form are more shallowly inundated than are sites occupied by cypress with more typical growth rates. Normally, this hydrologic regime should lead to relatively frequent fires and the elimination of these trees. However, the poor soils also limit growth of the marsh vegetation that dominates these sites. This results in a slower buildup of fuels and fewer or less severe fires, which in turn allows cypress to survive in what is otherwise a very unfavorable environment.

Trees which were large for their age were from two distinct groups. One contained cypress which had resprouted from stumps in several large clearcuts. Not only did these trees have the advantage of the extensive root system of the original logged trees, but they had full access to sunlight in the cutover area. In the second group were isolated trees along the edges of the undisturbed swamp forest and in canopy openings associated with larger ponds within the forest. In these areas, increased light availability or reduced competition could account for the relatively rapid growth of the trees.

ASSESSMENT OF CHANGES IN WATER QUALITY

Most of the vegetation occupying a freshwater floodplain forest in the upper part of small southeast Florida estuary had been killed sometime in the recent past, and the majority of the remaining bald cypress were in poor condition. The demise of this forest was generally attributed to saltwater intrusion following construction of a canal which diverted significant quantities of water from the upper part of the Loxahatchee River, the main tributary entering the estuary. This resulted in greatly reduced freshwater flows through the lower part of the river and most of the estuary. We were asked to use cypress tree rings from obviously impacted but still living trees to determine when the impacts began and whether the area impacted had stabilized or was continuing to expand upstream.

Our initial hypothesis was that there was a "date" in each core when a particularly distinct decrease in ring widths occurred and was maintained until we sampled the trees. We would then assess whether this change in growth (1) occurred at approximately the same time in all of the obviously stressed trees in the impacted area, and (2) was absent from trees located well upstream of the impacted area. Our sample design involved coring living cypress trees at several sites each within, at the upstream boundary, and above the affected area.

We did find the expected sharp transitions from large to consistently small rings in trees from the impacted area. We also noted that the "quality" of the rings showed a sharp transition from rings with well developed latewood bands to latewood bands which consistently had only a few poorly defined rows of cells. Both types of sharp transitions began to appear in a substantial number of trees about 1950 (Figure 6), which preceded construction of the diversion canal by ten years. However, this period did coincide with commencement of annual or biennial maintenance dredging of the mouth of the estuary for pleasure boat traffic in 1947. There was no comparable transition at this time in either ring widths or quality in cypress cores from sites upstream of the affected area.

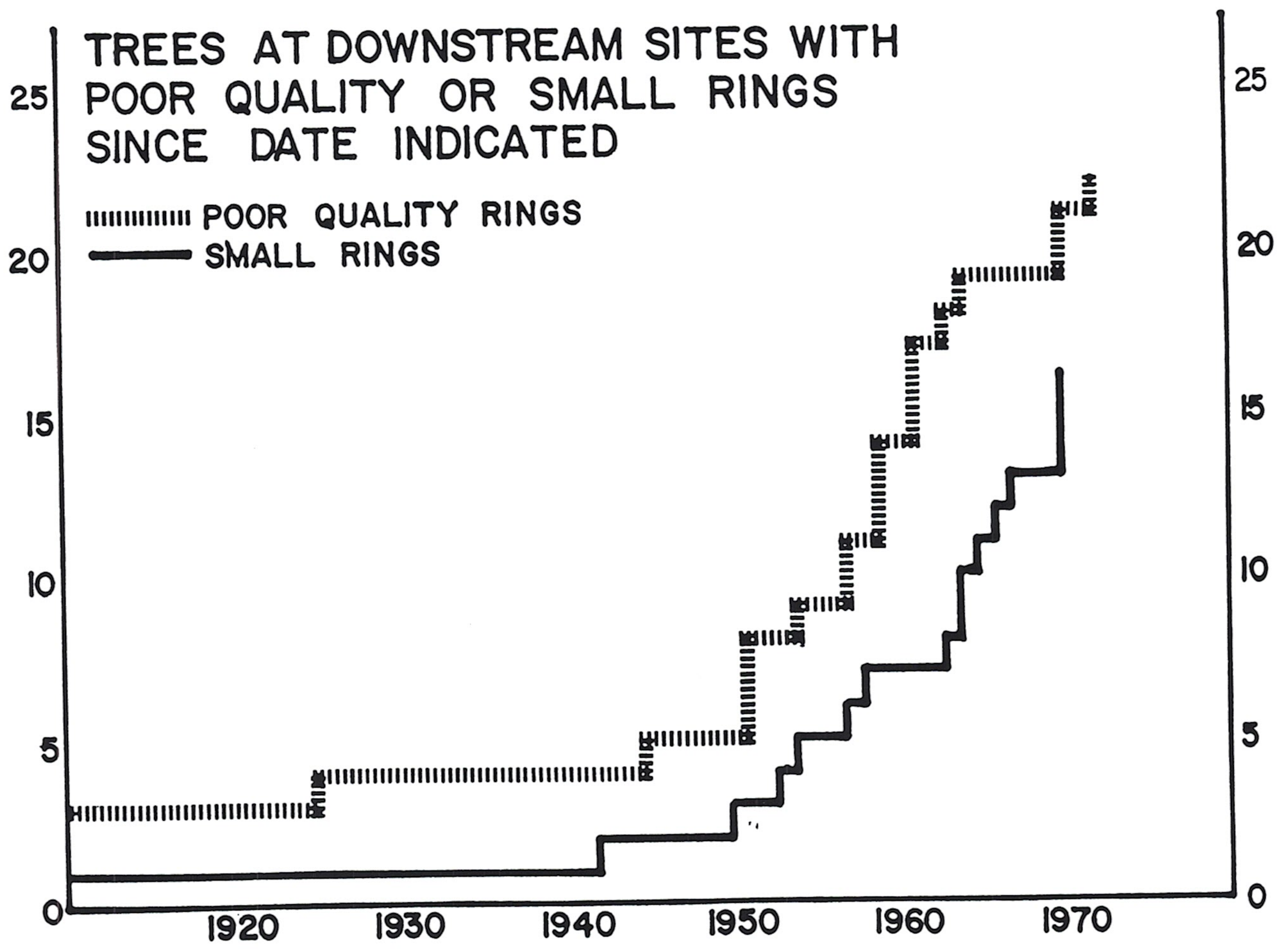


Figure 6. Cumulative numbers of cypress from the impacted portion of the Loxahatchee River floodplain forest which exhibited poor quality and/or small rings continuously since the date indicated. The total number of trees sampled in this area was 34.

Prior to regular dredging, the opening of the estuary into the Atlantic Ocean was always shallow and was frequently closed completely by sediment deposition from longshore currents during the winter-spring dry season when stream flows were low. Following dredging, greatly increased volumes of seawater entered the estuary. These inflows increased even more dramatically during periodic severe droughts, and undoubtedly resulted in especially high salinities in the upper part of the estuary due to high evaporation rates and lack of dilution at these times.

Thus, the maintenance of a permanent deepwater channel through the mouth of the estuary has permitted the movement of large quantities of seawater into parts of the estuary where before, it had rarely, if ever, been present. The diversion canal may have aggravated impacts on the floodplain forest, but its affects appear to be minor compared to the dredging activities. This is indicated by the lack of a significant increase in the rate at which trees were beginning to show a sharp transition to poor quality ring boundaries after 1960, either at the sites previously showing impacts or at sites further upstream (Figure 6). However, there was an increase in the rate at which trees began to show a sharp transition to consistently and distinctly smaller rings shortly after 1960. The data suggest that the characteristics of the latewood bands were more quickly affected by saltwater impacts than were the ring widths.

Analysis of data from the individual sampling sites in the impacted area of the floodplain showed that while some trees at each site began to show distinctly poorer growth between 1950 and 1959, others did not begin to show impacts until the 1960s or 1970s. Several factors seemed to account for these discrepancies. We did not sample dead trees because we were not crossdating, and therefore had to count back from the outermost ring of living trees to be able to "date" the sharp transition between normal and affected growth rings. Thus, those trees most likely to have felt the immediate impacts of saltwater intrusion following dredging were not available for sampling. Surviving trees included primarily stressed individuals, but also a few that still appeared vigorous. These trees are most likely still alive because they are in situations that are protected to varying degrees from saltwater intrusion, such as sites where groundwater flows enter the floodplain. As a result, the currently stressed trees probably represent individuals impacted only during occasional severe droughts which occurred subsequent to the commencement of regular dredging in the late 1940s.

In summary, tree-ring analysis showed us that the approximate date when visibly stressed cypress trees began to exhibit distinctly poorer growth was approximately ten years earlier than had previously been suspected. Examination of the timing of impacts on individual trees allowed us to develop a plausible explanation for why some trees were still alive in the impacted areas. This analysis also indicated that most of these trees will eventually be killed by saltwater intrusion, but the boundaries of the impacted area will not expand substantially.

ASSESSMENT OF CHANGES IN WATER QUANTITY

As part of our efforts to confirm that cypress does indeed lay down annual growth rings, we have counted tree-rings on samples from a number of stands of known age trees. One such set of cores from Corkscrew Swamp Sanctuary were from stump sprouts of trees logged in the early 1950s. The trees were located immediately above and below an old elevated earthen logging road which had been rebuilt in 1966 to impound water within the sanctuary and protect it from drainage by a major downstream development. In the course of analyzing these samples, we noticed a number of interesting patterns in the tree rings.

In addition to the expected decline in growth rates with age, there were several abrupt growth changes which correlated with hydrologic conditions (Figure 7). Immediately after construction of the dike in 1966 there was a striking decrease in cypress growth rates. This was followed by a return to normal growth in 1968, and another striking decrease in 1969 which was maintained until 1975, the year prior to our collecting the cores. Sanctuary hydrologic records revealed that abnormally high water levels and long hydroperiods prevailed around the dike from 1967 through 1973, except for 1968 when the dike was breached in several places by floodwaters and then repaired the following spring. Further evidence of the relationship between extended inundation and reduced growth rates was that 1960 was the only year prior to construction of the dike when this site was naturally inundated year-round and when cypress growth was also extremely poor. Thus, it appears that even one year of continuous inundation was sufficient to drastically slow cypress growth.

Although the trees immediately resumed rapid growth following a single year's flooding in 1960 and 1967, recovery after a more extended period of inundation apparently takes much longer. In 1974 and 1975, droughts permitted water levels to recede below ground each spring, but cypress growth rates remained below normal.

We sampled equal numbers of trees above and below the dike, primarily with the intention of generating replicate samples. However, during the data analyses, it became apparent that the patterns described above were applicable to both data sets. Since we had documented substantial differences in wet season water levels above and below the dike (Duever et al. 1975), the only hydrologic parameter which was likely to be affecting both sides of the dike equally was hydroperiod, the total number of days during the year that water exists above the ground surface. These values proved to be quite similar for both sides of the dike because of seepage through the porous substrate underlying it. Thus, it appears that the annual period of inundation was more significant in reducing cypress growth rates than was depth of inundation. This would agree with the concept that anaerobic conditions which characterize inundated wetland soils are a major factor influencing the productivity of these systems (Gosselink and Turner 1978, Mitsch and Gosselink 1986).

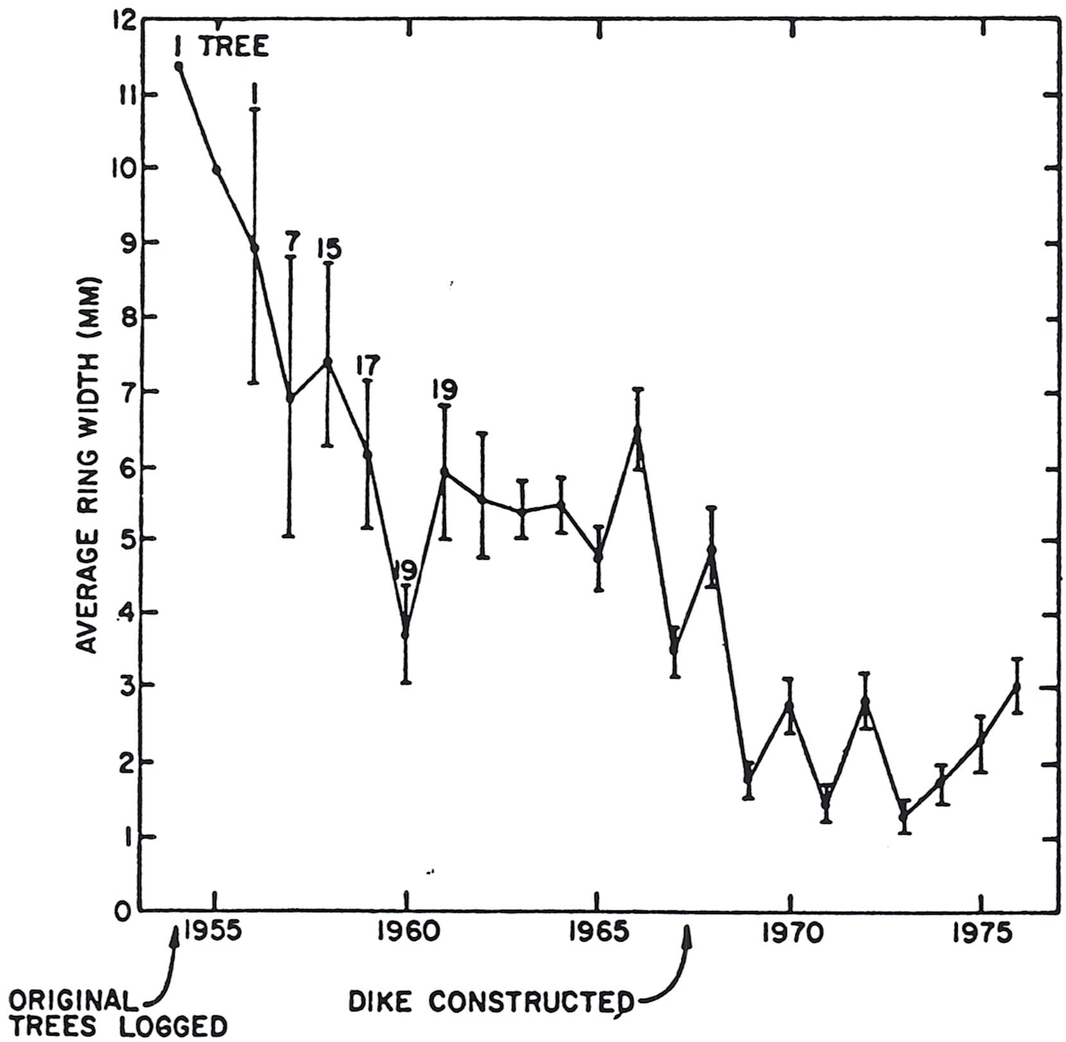


Figure 7. Average ring widths (± 1 S.E.) of cores from 20 cypress stump sprouts sampled along the South Dike at Corkscrew Swamp Sanctuary. The numbers above the S.E. bars are the number of cores with rings for these years, because some cores did not penetrate the pith of the tree.

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