Impacts of Mechanical Tree Felling on Development of Water Tupelo Regeneration in the Mobile Delta, Alabama

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ABSTRACT: *Two water tupelo (*Nyssa aquatica *L.) stands in the Mobile Delta of Alabama were selected to test the hypothesis that mechanized felling does not reduce establishment and growth of natural water tupelo regeneration relative to traditional tree felling with chainsaws. To test the hypothesis, we established six, 2 ac treatment plots in each of two blocks on each of two sites, and randomly assigned plots to either mechanical tree felling with a tracked, swing feller or chainsaw felling. Each site was clearcut in Fall, 1992, and merchantable boles were removed by helicopter. Establishment and growth of regeneration was assessed prior to harvest and annually for 3 yr after harvest in five, 0.01 ac measurement plots located in each treatment plot. Stand harvesting promoted establishment of water tupelo seedlings such that 3 yr after treatment we recorded over 270/ac on each site regardless of felling method. Seedling height increased at a steady rate and averaged about 39 in. tall after three growing seasons. Woody competition also responded to the harvest, outnumbering water tupelo seedlings 3 yr after treatment by as much as seven to one on Site 2. Water tupelo stump sprouts developing from chainsaw felling grew well and averaged about 13.5 ft tall after three growing seasons. However, mechanical felling reduced water tupelo stump sprouting by 50% leading to a lower density of sprout clumps in mechanically felled plots (*P *= 0.0253). Our results indicated that mechanical felling techniques used in this study may adversely impact regeneration of water tupelo swamps where coppice is a desirable form of reproduction. South. J. Appl. For. 24(2):65–69.*

Water tupelo *(Nyssa aquatica* L.), a tree of sloughs and deep swamp sites in wetland forests, ranges across the southern United States from southeastern Virginia to southeastern Texas and northward through the Mississippi Alluvial Valley to southern Illinois (Johnson 1990). A conservative estimate of 2 9 million ac of forested wetlands are occupied by water tupelo and its most common associate, baldcypress (*Taxodium distichum* [L.] Rich.) (Conner and Buford 1998). Because the swampy sites occupied by water tupelo are characteristically inundated, this species is well adapted for growth in anaerobic soils and is able to utilize annual inflows of nutrient rich water received by swamp basins. Consequently, the swamp sites on which water tupelo thrives can be among the most productive of southern forests (Conner and Day 1976, Hodges 1995), supporting stands with basal areas in excess of 400 ft^2/ac and mean annual volume increments greater than 150 ft^3/ac/yr (Kellison and Young 1997). This exceptional productivity perpetuates the value of water tupelo as a source of fiber and lumber, but the annual inundations that maintain the productivity of swamp forests create logistical and environmental concerns for harvesting operations.

Early lumbermen met the challenges of harvesting bottomland swamps through development of railroad logging and the pullboat, a barge-mounted skidder capable of winching felled logs nearly a mile through the swamp (Mancil 1980). Though effective in extracting felled logs from the swamp, pullboat "runs" remain as an indelible reminder of early harvesting in swamps across the southern United States. Modern loggers realize that maintenance of wetland functioning hinges on limiting hydrologic alterations, limiting soil disturbance, and ensuring adequate stocking of the future stand during the regeneration harvest (Aust and Lea 1992, Lockaby et al. 1997). Yet there can be improved efficiency

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and increased job-site safety through mechanization of harvesting processes (Stokes and Shilling 1997). Thus there is a critical need to develop harvesting equipment and methods suitable for use on wetland soils. One method currently employed in swamps of the Mobile Delta involves the use of a tracked, swing feller that maneuvers above the soil surface on portable wooden mats. The portable mats reduce soil impacts by displacing the weight of the feller over a large surface area. Once trees are felled, ground crews attach choker cables to merchantable boles, which are extracted from the swamp with a helicopter (Willingham 1989).

Although the operation described by Willingham (1989) can be efficient for harvesting wetland sites, the impact of the feller on establishment and growth of water tupelo regeneration is not known. Mechanized harvesting operations can potentially affect regeneration of wetland sites, especially by altering hydroperiods and destroying vegetative reproduction (Lloyd et al. 1992, Lockaby et al. 1997). In this study, we tested the hypothesis that tree felling with a tracked, swing feller which maneuvers on portable mats does not reduce establishment and growth of natural water tupelo regeneration relative to the more labor intensive practice of tree felling with chainsaws.

Methods

The experiment was conducted on two water tupelo sites owned by Kimberly-Clark Corporation and adjacent to the Tensaw River in the Mobile Delta, Baldwin County, AL. Average annual rainfall in the county is more than 64 in., average temperature is 67.4°F, and the growing season typically extends from March 5 to November 22 (McBride and Burgess 1964). Preharvest basal area on Site 1 averaged 250 ft^2/ac [278 trees/ac (79% water tupelo)], and about 20% of the forest floor was occupied by herbaceous cover. Site 2, which was located several miles downstream from the first, was about 2 ft lower in elevation and was subsequently subject to greater tidal influence. Preharvest basal area averaged 235 ft^2/ac [291 trees/ac (58% water tupelo)], and herbaceous ground cover was estimated at about 60%. Soils on both sites were classified in the Levy series (fine, mixed, acid, thermic Typic Hydraquents).

Twelve, 2 ac plots were delineated on each site. Since elevation decreased away from the river front, plots were arranged in two blocks. Plots nearest the river front were assigned to Block 1, and those furthest from the front were assigned to Block 2. Felling method was randomly assigned to each 2 ac experimental unit. In the mechanical felling treatment, all stems were felled with a tracked, swing feller that maneuvered through the swamp on portable wooden mats. Potential effects on the site and tree regeneration with this treatment included felling machinery maneuvering on the site, felled trees, and feller damage to stumps from mats and sawhead. In the operational control treatment, sawyers felled all stems with chainsaws. Impact on the site and regeneration with traditional chainsaw felling was potentially from sawyer foot traffic and ground impact from felled trees. All stems greater than about 2 in. dbh were severed during clearcutting, and all merchantable boles were removed from the site with a helicopter. Both sites were harvested in late Fall 1992 during a dry period when standing water was absent from the soil surface.

Vegetation responses were measured in a series of five, 0.01 ac circular subplots established in each 2 ac treatment plot. Preharvest records included species and height (for seedlings < 4.5 ft tall) or dbh (for trees and saplings > 4.5 ft tall) of all woody plants. Measurements collected annually for 3 yr post-harvest included species, seedling height, and height of the tallest sprout in each stump sprout clump Repeated measures analysis of variance were conducted on plot averages for pre- and post-harvest data to determine significance of treatment effects on density of water tupelo regeneration, density of competing regeneration, height of water tupelo seedlings, and height of water tupelo stump sprouts. The analyses were conducted according to a randomized block design and significance determined at an alpha level of 0.05.

Results

Repeated measures analyses revealed a significant year effect (P = 0.0001) on all response variables analyzed Interactions between year and treatment were not detected for any of the response variables. Block effects did not account for a significant amount of the variation in establishment or growth of water tupelo seedlings, sprouts, or competition. Thus, block effects will not be reported or discussed. Effects of site and felling method on water tupelo regeneration and competition are presented and discussed below.

Establishment of Water Tupelo and Competing Regeneration

Prior to harvest, the regeneration pool on each site was void of water tupelo seedlings. Water tupelo regeneration responded to harvesting with a profuse establishment of seedlings on both sites (Figure 1a). Following the initial response, density of water tupelo seedlings decreased on each site to about 270 seedlings/ac, 3 yr after harvest (Figure 1a) Felling method did not affect establishment or survival of water tupelo seedlings during the initial 3 yr of stand development (P = 0.2099) (Figure 1b).

Though most of the water tupelo ingrowth was attributed to seedling establishment from the seed bank (Figure 2), the tupelo regeneration pool on each site also had about 150 viable stump sprout clumps (P = 0.9872) (Figure 3a). Sprout clump density was similar on each site, but Site 2 had fewer water tupelo trees pre-harvest (Site 1 = 219 trees/ac, Site 2 = 168 trees/ac) indicating that water tupelo sprouting was greatest on this site. Mortality of tupelo sprout clumps progressed at the same rate on each site, and 3 yr after treatment, we recorded about 120 sprout clumps/ac (P = 0.8456) (Figure 3a). Since seedling mortality progressed quicker than sprout mortality, the relative importance of sprouts in the regeneration pool increased over time (Figure 2).

Mechanical felling severely reduced the likelihood of water tupelo stump sprouting. After three growing seasons, 81% of water tupelo trees felled with a chainsaw maintained a live stump sprout, while only 44% of tupelo trees felled

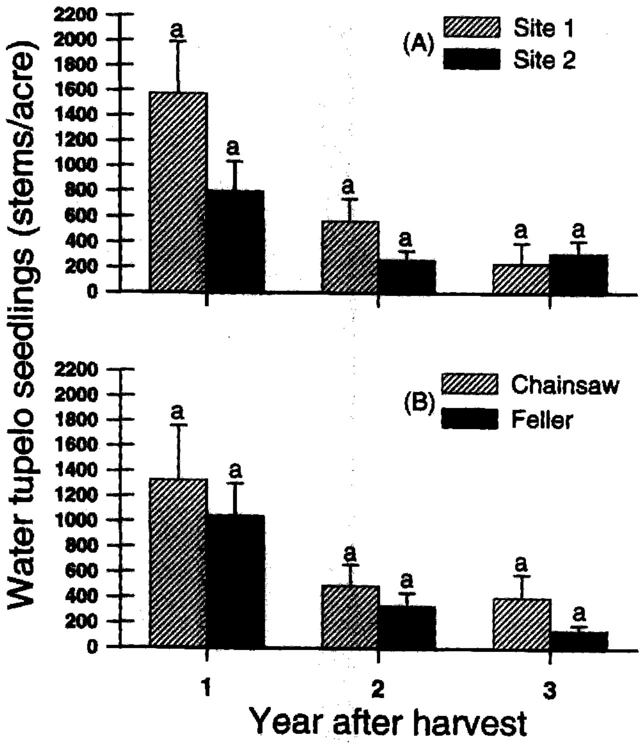

Figure 1. Average density of water tupelo seedlings according to site (A) and felling method (B) for 3 yr post-harvest in the Mobile Delta, AL. Error bars represent ±1 standard error of the mean. Significant treatment effects for a year are noted by different letters above the bar ($\alpha = 0.05$).

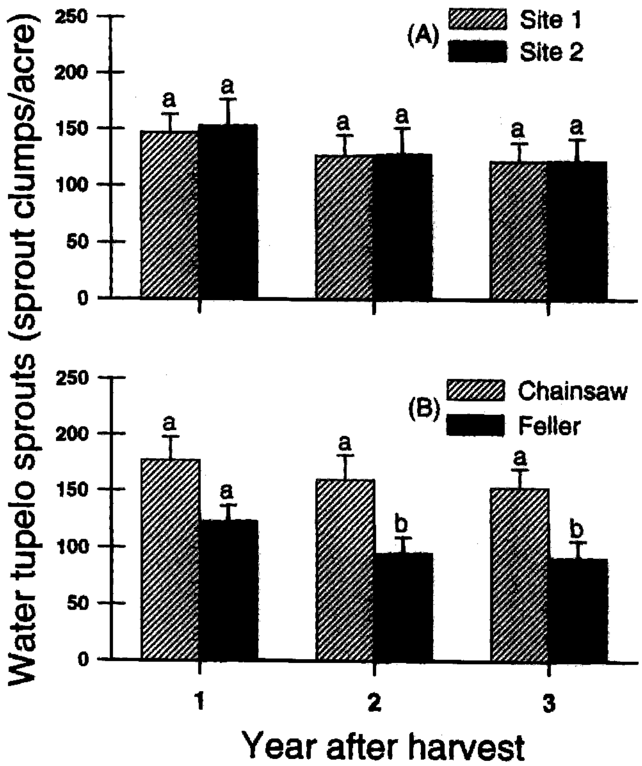

Figure 3. Average density of water tupelo sprout clumps according to site (A) and felling method (B) for 3 yr post-harvest in the Mobile Delta, AL. Error bars represent ±1 standard error of the mean. Significant treatment effects for a year are noted by different letters above the bar ($\alpha = 0.05$).

mechanically supported a stump sprout. The reduced stump sprouting of trees felled mechanically affected density of water tupelo sprout clumps by the second year after harvest ($P = 0.0463$) (Figure 3b). This observation was maintained through year three, as density of sprout clumps was 40% lower in mechanically felled plots than in chainsaw plots ($P = 0\ 0253$) (Figure 3b).

Prior to harvesting, density of woody competition ranged from 590 stems/ac to 1,650 stems/ac, with the highest level occurring on Site 2 ($P < 0.0001$) (Figure 4a). Seedlings of baldcypress and black willow (*Salix nigra* Marsh.), along with coppice from baldcypress, Carolina ash (*Fraxinus caroliniana* Mill.), Virginia-willow (*Itea virginica* L.), and winterberry (*Ilex verticillata* [L.] Gray) grew vigorously on each site immediately after harvest. Highest densities of competition were recorded the first year following harvest on Site 1, while density of competition peaked on Site 2 two yr after harvest. The greatest level of competition after 3 yr was maintained on Site 2 where other woody species outnumbered water tupelo regeneration seven to one ($P < 0.0001$) (Figure 4a). In contrast to our findings for water tupelo stump sprouts, density of woody competition was not influenced by felling method ($P = 0.9376$ for year 3) (Figure 4b).

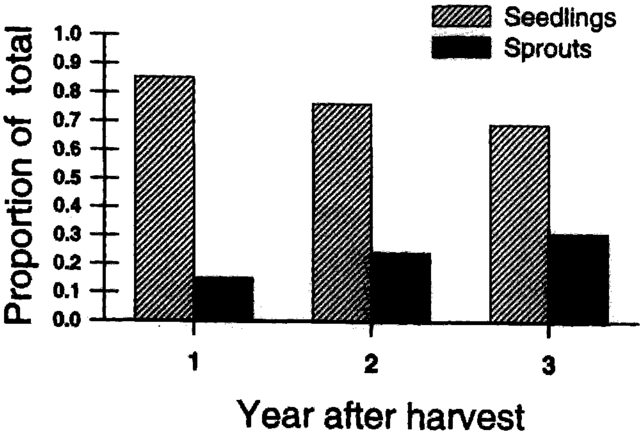

Figure 2. Proportion of water tupelo seedlings and stump sprouts 1 yr pre- and 3 yr post-harvest on two sites in the Mobile Delta, AL.

Water Tupelo Growth

One year after harvest, water tupelo seedlings established on Site 2 were about 2 in. taller than those established on Site 1 ($P < 0.0001$) (Figure 5a). However, this effect was lost in subsequent years as seedlings showed similar heights across sites by year two ($P = 0.9191$) (Figure 5a). Established seedlings nearly doubled in height each growing season so that 3 yr after the regeneration cut, they were about 39 in. tall on each site ($P = 0.8830$) (Figure 5a). Felling method did not influence height of water tupelo seedlings during the course of this study ($P = 0.5159$) (Figure 5b).

Where stumps survived, water tupelo sprouts quickly dominated each site exhibiting vigorous growth that averaged more than 13.5 ft after three growing seasons ($P = 0.8201$) (Figure 6a). One year after harvest, sprout height in mechanically felled plots was about 16% shorter than in chainsaw plots ($P = 0.0035$) (Figure 5b). However, this initial difference diminished as coppice developed over three growing seasons ($P = 0.0571$) (Figure 6b).

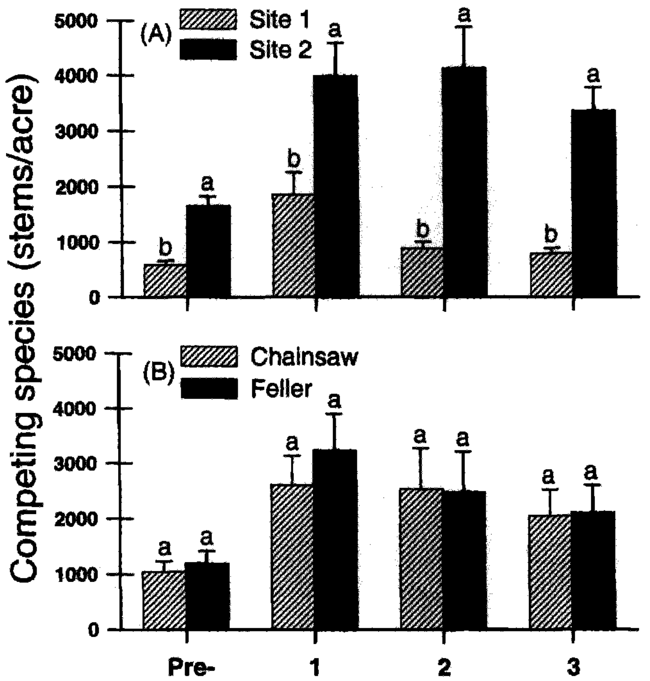

Figure 4. Average density of competing regeneration according to site (A) and felling method (B) for 1 yr pre- and 3 yr post-harvest in the Mobile Delta, AL. Error bars represent ± 1 standard error of the mean. Significant treatment effects for a year are noted by different letters above the bar (α = 0.05).

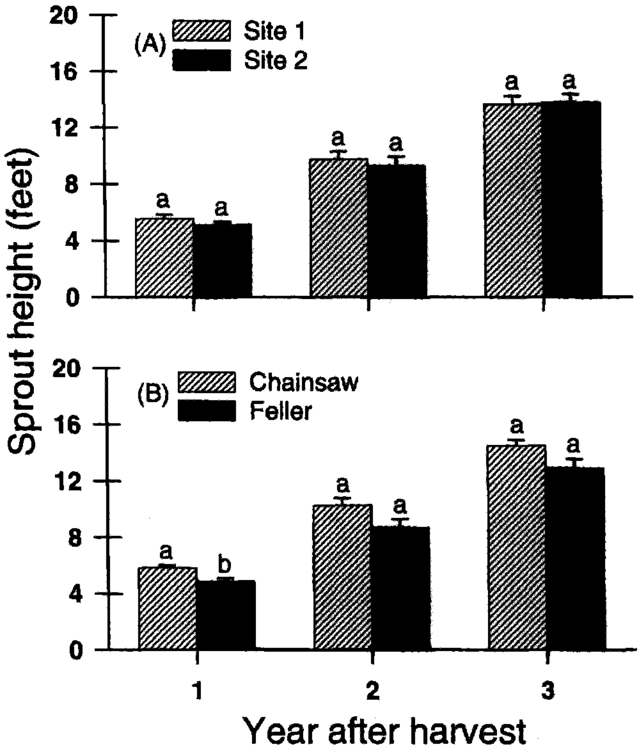

Figure 6. Average height of water tupelo stump sprouts according to site (A) and felling method (B) for 3 yr post-harvest in the Mobile Delta, AL. Error bars represent ±1 standard error of the mean. Significant treatment effects for a year are noted by different letters above the bar (α = 0.05).

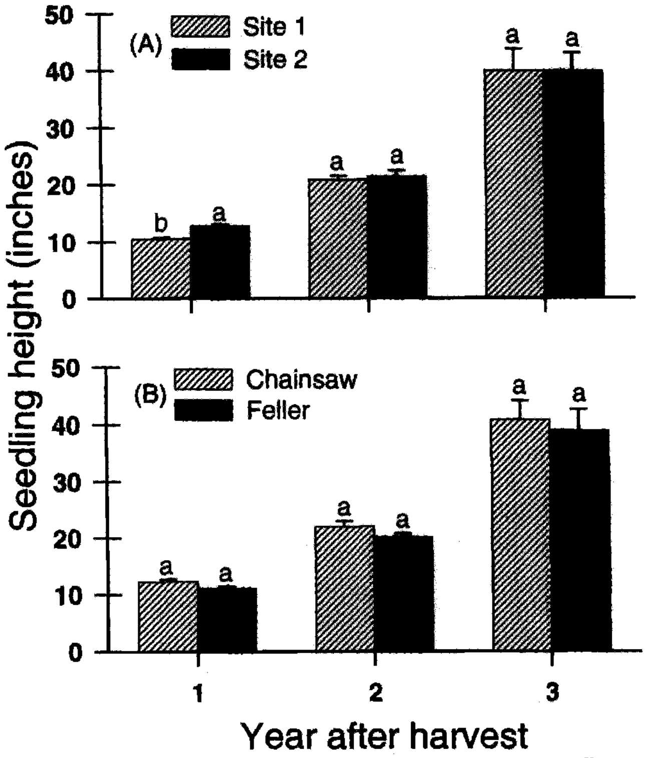

Figure 5. Average height of water tupelo seedlings according to site (A) and felling method (B) for 3 yr post-harvest in the Mobile Delta, AL. Error bars represent ±1 standard error of the mean. Significant treatment effects for a year are noted by different letters above the bar (α = 0.05).

Discussion

Harvesting promoted a tremendous ingrowth of water tupelo seedlings on each site regardless of felling method Given a favorable dry period the growing season after harvest, germination and seedling establishment were in lıne with our expectations, as water tupelo is a prolific seeder and its seed may remain viable for at least 1 yr (Johnson 1990) A fair number of water tupelo seedlings (over 270/ac on each site) survived after three growing seasons, and we were unable to detect a felling method effect on density or growth of these seedlings. In spite of the favorable establishment and growth of the water tupelo seedlings, we do not know if they will develop into dominant or codominant canopy positıons amid the woody competition. We speculate that some of the water tupelo seedlings will develop into canopy trees, because they exhibited good height growth and over 50% of the competing vegetation was shrub and midstory species (data not shown). Furthermore, water tupelo stump sprouts were more competitive than seedlings and will likely maintaın canopy dominance.

By the end of this study, water tupelo stumps remaınıng from trees that were mechanically felled were half as lıkely to support a live sprout than stumps of chainsaw-felled trees Others have noted damage to coppice reproduction in mechanically harvested bottomlands. For example, Lloyd et al (1992) reported a 40% loss of coppice reproduction for a southern Alabama blackwater bottom and attributed thıs mortality to felling and skidding machinery. Lockaby et al. (1997) surmised that species that regenerate via coppıce reproduction are inhibited by ground-based logging operations because of root and stump damage caused by machinery However, Aust et al. (1997) did not report evidence of damaged coppice reproduction in their study of a water tupelo stand that received rubber-tired skidder traffic. Stump damage we observed on mechanically felled trees in this study included partially uprooted stumps, stumps with missing bark or slabs, and stumps severed near groundline to allow for positioning of portable mats. We suggest that the damage sustained by water tupelo stumps from the mechanical felling process was probably the principle cause of reduced sprouting.

In addition to lowering stump viability, damage sustained from the mechanical feller initially reduced sprout vigor. The stump damage we noted above could have possibly reduced carbohydrate availability or predisposed sprouts to moisture or flooding stress. However, the initial reduction in sprout vigor was not apparent by the end of the study.

The impact of mechanized felling on coppice reproduction contributed to an overall lower density of water tupelo sprout clumps in mechanically felled plots. This finding raises concern over mechanical felling in water tupelo swamps, especially if stump sprouts are integral to maintaining the tupelo component in the stand. Yet, the reliability of water tupelo stump sprouts for regeneration seems to vary across the species range. In the Atchafalaya Basin of Louisiana, Kennedy (1982) observed substantial stump rotting and sprout mortality which precluded adequate coppice regeneration of tupelo in that swamp. In contrast, Hook et al. (1967) described prolific stump sprouting of water tupelo stumps in South Carolina swamps. And, Aust et al. (1997), who worked in the Mobile Delta, indicated that stump sprouts were the source of over 80% of the overstory on their study site. The reproductive value of stump sprouts on our study sites in the Mobile Delta was illustrated by the proportional increase of sprouts during the initial three yr of stand development. Thus, we feel that substantial reductions in the amount of coppice reproduction on our study sites could potentially lead to a reduced level of water tupelo stocking and reduced productivity in the developing stand. Indeed, the rapid vegetative growth of coppice reproduction contributed to the recovery of productivity in the harvested water tupelo swamp studied by Aust et al. (1997).

Conclusions

This study was initiated in the Mobile Delta to test the hypothesis that mechanized felling does not reduce survival and growth of water tupelo regeneration relative to traditional tree felling by sawyers. Three years of observations indicated that establishment and growth of water tupelo seedlings were not detrimentally impacted by mechanical tree felling. Yet, the competitiveness of these young water tupelo seedlings is questioned when viewed in relation to density of other woody species. In light of the early stand composition and regeneration dynamics we observed in this study, it appears that stump sprouts are important for replacement of water tupelo in the Mobile Delta. Mechanical felling substantially reduced water tupelo stump sprouting. Based on our observations of seedling establishment, we speculate that some water tupelo seedlings will be available to occupy gaps where coppice reproduction failed. However, regeneration stocking levels needed to sustain water tupelo dominance in stands of the Mobile Delta are not known. We speculate that mechanical tree felling as used in this experiment will delay the return of the stand to full stocking. Future investigations will be necessary to determine if seedlings do attain canopy dominance and if the stump mortality associated with mechanical felling will alter stand development and compromise future water tupelo productivity.

Literature Cited

AUST, W.M., AND R. LEA. 1992. Comparative effects of aerial and ground logging on soil properties in a tupelo-cypress wetland. For. Ecol. Manage. 50:57–73.

AUST, W.M., S.H. SCHOENHOLTZ, T.W. ZAEBST, AND B.A. SZABO. 1997. Recovery status of a tupelo-cypress wetland seven years after disturbance: silvicultural implications. For. Ecol. Manage. 90(2,3):161–169.

CONNER, W.H., AND M.A. BUFORD. 1998. Southern deepwater swamps. P. 261–287 *in* Southern forested wetlands ecology, Messina, M.G., and W.H. Conner (eds.). CRC Press LLC, Boca Raton, FL.

CONNER, W.H., AND J.W. DAY, JR. 1976. Productivity and composition of a baldcypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. Am. J. Bot. 63(10):1353–1364.

HODGES, J.D. 1995. The southern bottomland hardwood region and brown loam bluffs subregion. P. 227–269 *in* Regional silviculture of the United States, Barrett, J.W. (ed.). Wiley, New York.

HOOK, D.D., W.P. LEGRANDE, AND O.G. LANGDON. 1967. Stump sprouts on water tupelo. South. Lumberman 215:111–112.

JOHNSON, R.L. 1990. *Nyssa aquatica* L. water tupelo. P. 474–478 *in* Silvics of North America, Vol. 2, Hardwoods, Burns, R.M., and B.H. Honkala (Tech. Coords). Agric. Handb. 654., Washington DC.

KELLISON, R.C., AND M.J. YOUNG. 1997. The bottomland hardwood forest of the southern United States. For. Ecol. Manage. 90(2,3):101–115.

KENNEDY, H.E., JR. 1982. Growth and survival of water tupelo coppice regeneration after six growing seasons. South. J. Appl. For. 6(3):133–135.

LLOYD, S.M., R.H. JONES, AND B.G. LOCKABY. 1992. Effects of harvesting on tree regeneration in three Alabama branch bottom forests. P. 869–873 *in* Wetlands, Proc. of the 13th Annual Conf., Landin, M. (ed.). Society of Wetland Scientists, New Orleans, LA.

LOCKABY, B.G., J.A. STANTURF, AND M.G. MESSINA. 1997. Effects of silvicultural activity on ecological processes in floodplain forests of the southern United States: a review of existing reports. For. Ecol. Manage. 90(2,3):93–100.

MCBRIDE, E.H., AND L.H. BURGESS. 1964. Soil survey of Baldwin County, Alabama. USDA—Soil Conserv. Serv. Series 1960, No. 12. 110 p.

Mancil, E. 1980. Pullboat logging. J. For. Hist. 24:135–141.

STOKES, B.J., AND A. SCHILLING. 1997. Improved harvesting systems for wet sites. For. Ecol. Manage. 90(2,3):155–160.

WILLINGHAM, P. 1989. Wetland harvesting systems for the Mobile delta. P. 148–151 *in* Proc. of the South. Reg. Counc. on Forest Eng., Stokes, B.J. (ed.). USDA For. Serv., South. For. Exp. Sta., New Orleans, LA.