LONG-TERM SUCCESS OF STUMP SPROUT REGENERATION IN BALDCYPRESS

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Abstract—Baldcypress [*Taxodium distichum* (L.) Rich.] is one of very few conifers that produces stump sprouts capable of becoming full-grown trees. Previous studies have addressed early survival of baldcypress stump sprouts but have not addressed the likelihood of sprouts becoming an important component of mature stands. We surveyed stands throughout south Louisiana, selectively harvested 10 to 41 years ago, to determine whether stump sprouts are an important mechanism of regeneration. At each site we inventoried stumps and measured stump height and diameter, presence and number of sprouts, sprout height, and water depth. We determined age and diameter growth rate for the largest sprout from each stump from increment cores. The majority of stumps did not have surviving sprouts. Sprouts that did survive were generally vigorous, but rot from stumps often appeared to be spreading into the bases of sprouts. Within the stands studied, baldcypress stump sprouts did not appear to be able to consistently produce viable regeneration sufficient for long-term establishment of well-stocked stands.

INTRODUCTION

Cut stumps of cypress (*Taxodium* spp.) often produce sprouts from latent or adventitious buds and are some of the very few conifers that produce sprouts capable of becoming full-grown trees (Wilhite and Toliver 1990). This mechanism of regeneration is an attractive option in cypress silviculture, because seedling establishment is often not reliable on the frequently flooded sites where it dominates (Conner and others 1981, Conner and Toliver 1990, Conner and others 1986, Wilhite and Toliver 1990).

Coppice regeneration of baldcypress [*T. distichum* (L.) Rich.] and water tupelo (*Nyssa aquatica* L.) is currently of special interest in Louisiana. There are approximately 345,000 ha of baldcypress-tupelo (*Nyssa* spp.) forest in coastal Louisiana, most of which were clearcut from about 1890 to 1930 (Chambers and others 2005, Conner and Toliver 1990) and subsequently regenerated into even-aged stands. Extensive construction of levees, canals, and other water control structures since the initial logging of these swamps has combined with eustatic sea-level rise and land subsidence to create widespread and pervasive changes of hydrological conditions in these forests (Conner and Day 1988, Pezeshki and others 1990, Salinas and others 1986). Thus, although the second-growth baldcypress-tupelo forests are now commercially attractive for harvesting, many stands may not regenerate naturally by seed. The viability of coppice regeneration is therefore important in designing sustainable silvicultural systems for Louisiana baldcypress and water tupelo regeneration.

Both baldcypress and water tupelo readily produce stump sprouts, though sprouting is less prolific from stumps of older (> 60 years) trees (Mattoon 1915) or from stumps of trees cut in the spring or summer (Williston and others 1980). Stump height, felling method, and harvesting level can also influence the viability of stumps and vigor of sprouts (Ewel 1996, Gardiner and others 2000, Hook and DeBell 1970, Kennedy 1982). Although sprouting usually does occur, some investigators have observed poor growth and survival of stump sprouts. Conner and others (1986) reported that 80 percent of baldcypress stumps sprouted after logging, but fewer than 25 percent retained live sprouts 4 years after harvest. Conner (1988), summarizing a number of studies in Louisiana, found 0 to 23 percent of baldcypress stumps with surviving sprouts after 4 to 7 years. Similarly, Ewel (1996) reported only 17 percent survival of pondcypress (*T. ascendens* Brongn.) stump sprouts a few years after harvests in Florida swamps.

The goal of this research was to evaluate potential of harvested stands to regenerate, become established, and remain productive through stump sprouting. Adequate assessment of the viability of coppice regeneration for regenerating baldcypress-tupelo stands in the context of coastal Louisiana's modified hydrological conditions requires better information about survival and growth of stump sprouts beyond the short time scale of previous research. Therefore, we conducted a regeneration survey of sites harvested 10 or more years earlier. The specific objectives were to (1) determine whether stump sprouts in baldcypress and water tupelo continued to experience the high mortality rates characteristic of the first 7

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years after harvest, and (2) assess whether surviving sprouts would be sufficient to form viable new stands.

METHODS

Suitable sites for this survey were in coastal Louisiana, dominated by baldcypress and water tupelo, and harvested nominally 10 to 50 years earlier. Field experience suggested that rot in baldcypress stumps older than 50 years would be so complete as to prevent assessment of stump sprouting rates. We contacted land owners, foresters, and researchers to find sites meeting these criteria and surveyed 18 sites for stump sprout and seedling regeneration (fig. 1). Information about site history, specific silvicultural goals, and logging methods was incomplete for most sites. Harvesting of most sites consisted mainly of diameter-limit cutting of baldcypress with less cutting of other species. Thus, stumps were mainly larger in diameter than were the remaining overstory trees in most stands.

Sampling at each site was done using a series of transects, 12 m wide and 30 m long, placed irregularly to encompass stumps from the previous harvest. We placed at least 5 transects per site or as many additional transects as necessary to sample 30 stumps per site. In each transect, we measured diameter of all trees and tall shrubs (woody vegetation >1 cm d.b.h.) and counted seedlings of baldcypress and water tupelo that were < 1.37-m tall. Measurements at each stump included height and diameter, depth of water adjacent to the stump, number of live sprouts, diameter and height of the largest sprout, and distance from the stump to the nearest–neighbor canopy tree.

We collected cores from several baldcypress with an increment borer to determine ages and historical growth of trees, saplings, and stump sprouts. We assumed all trees were 3 years old at breast height, and we cored all sprouts near the base within what we assumed to be the first year's growth. We dried, mounted, and sanded cores to aid in visual identification of annual growth rings. After identifying false rings (Young and others 1993) and eliminating them from analysis, we used a measuring stage designed for tree core analysis under 10 to 100 power magnification to measure ring width to ± 0.1 mm.

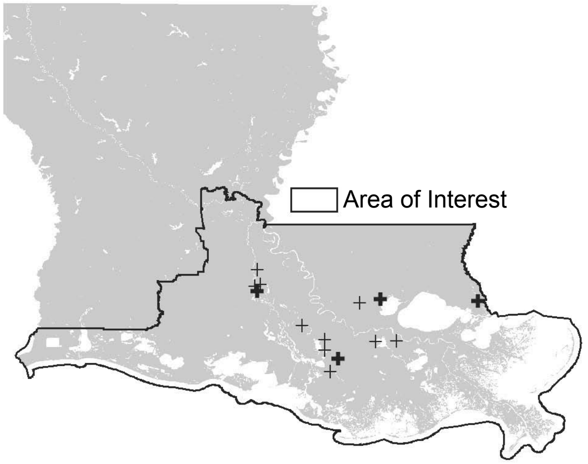

Figure 1—Site locations in south Louisiana for coastal baldcypress–tupelo stump sprouting survey. Bold crosses represent the location of two sites.

There was a substantial variety of conditions in the sampled sites. Soils were of mineral and organic origin, and hydrological regimes ranged from permanent flooding to seasonal, riverine flooding. Most sites were in blackwater backswamp areas flooded mainly by rain water, but some were near river fronts. Understory vegetation, an indicator of growing-season flooding, ranged from bare ground to thick, emergent aquatic vegetation characteristic of treeless marshes (table 1).

RESULTS

Across the sites, relative basal area of standing baldcypress ranged from 6.7 to 97.5 percent, and water tupelo ranged from 0 to 93.2 percent (table 1). Baldcypress and tupelo together represented 66 to 100 percent of the stand basal area and exceeded 75 percent on 15 of the 18 sites. Other common woody species included green ash (*Fraxinus pennsylvanica* Marsh.), pumpkin ash (*F. profunda* Bush), swamp red maple [*Acer rubrum* var. *drummondii* (Hook. & Arn. ex Nutt.) Sarg.], buttonbush (*Cephalanthus occidentalis* L.), swamp privet [*Forestiera acuminata* (Michx.) Poir.], Virginia-willow (*Itea virginica* L.), and waxmyrtle [*Morella cerifera* (L.) Small]. A few sites were in mixed cypress-tupelo-bottomland hardwood forests, where common overstory species also included water hickory [*Carya aquatica* (Michx. F.) Nutt.], sugarberry (*Celtis laevigata* Willd.), water locust (*Gleditsia aquatica* Marsh.), water-elm (*Planera aquatica* J.F. Gmel.), black willow (*Salix nigra* Marsh.), and Chinese tallow [*Triadica sebifera* (L.) Small].

Stumps of water tupelo were characteristically too degraded for assessment of stump sprouting potential; the few nonsprouting stumps remaining were barely recognizable and impossible to measure. Additionally, we found live tupelo sprouts at only 2 adjacent sites (16 and 17). Because site history was largely unknown, it was not always clear whether the absence of water tupelo stumps was because (1) it was absent from the stand at the time of logging, (2) it was not cut during logging, or (3) sprout mortality and stump decomposition were rapid. In contrast, baldcypress stumps were intact, easily recognizable, and amenable to analysis for long-term stump sprout survival and growth.

The proportion of baldcypress stumps having live sprouts ranged from 0 to 72 percent by site (median 10 percent; table 2). However, only 2 of the 18 sites had live sprouts on more than 20 percent of stumps. On four sites, no stumps had live sprouts. There was no relationship between time since harvest and sprout survival ($R^2 = 0.06$). The spatial distribution of surviving stump sprouts was uneven, so that some sites had surviving stump sprouts on only one or two sampling transects. We were unable to determine the reason for such variability.

The average diameter of the largest live sprout per stump across all sites was 10 cm, while the average height was 6.8 m. Normalized for sprout age, site-average diameter mean annual increment (MAI) ranged from 0.17 to 0.99 cm yr^{-1}, and site-average height MAI ranged from 0.15 to 0.82 m yr^{-1}. Site-average stump sprout MAI was moderately correlated to proportional survival ($R^2 = 0.56$ for height and 0.49 for diameter) (fig. 2A). Sprout MAI was also negatively (but slightly) correlated with age ($R^2 = 0.37$ for height and 0.27 for diameter; fig. 2B).

Table 1—Characteristics of the surveyed stands in south Louisiana

			Tree		Rel. basal area[d]		Cypress	Aquatic
Site	Harvest[a]	Age[b]	basal area	Trees	cypress	tupelo	seedlings	vegetation
			(m^2 ha^{-1})[c]	*(ha^{-1})*[c]	- - - - - % - - - - -		*ha^{-1}*	
1	I	20	54.3	331	91	9	953	Scattered
2	P	20	68.9	511	94	4	267	Heavy
3	P	19	50.2	459	68	31	0	Light
4	P	18	74.3	573	88	10	0	Heavy
5	P	24	93.7	1,067	98	3	0	None
6	C	11	47.8	578	75	24	0	Heavy
7	P	11	48.0	729	62	37	0	Heavy
8	P	10	26.5	553	57	9	0	Scattered
9	P	10	52.8	531	67	4	0	None
10	P	24	43.9	457	59	37	40	Light
11	P	17	63.0	852	79	2	0	None
12	P	9	29.2	514	66	0	109	None
13	P	8	57.8	420	78	0	0	None
14	P	1	80.8	694	87	0	0	None
15	P	8	66.0	531	83	1	0	None
16[e]	C	18	97.5	872	7	93	27	None
17[e]	I	22	50.9	674	16	85	54	None
18	P	41	58.7	766	56	24	0	None

[a] I=improvement cut; silvicultural thinning. P = partial cut; diameter-limit cut. C = clearcut.
[b] Time between harvest and sampling in 2004.
[c] Includes all currently standing trees and baldcypress cut stumps.
[d] Relative basal area of standing trees only.
[e] Sites dominated by water tupelo; too few baldcypress stumps for analysis.

Table 2—Baldcypress stump and sprout characteristics for the surveyed stand in south Louisiana

			Baldcypress stumps			Sprout MAI	
Site	Harvest[a]	Age[b]	Total	with sprouts	%sprouts	Diameter	Height
						cm yr^{-1}	*m yr^{-1}*
1	I	20	29	2	6.9	0.46	0.16
2	P	20	30	5	16.7	0.58	0.50
3	P	19	31	6	19.4	0.67	0.46
4	P	18	35	6	17.1	0.92	0.53
5	P	24	64	3	4.7	0.17	0.15
6	C	11	33	24	72.7	0.99	0.75
7	P	11	22	14	63.6	0.99	0.82
8	P	10	25	0	0.0		
9	P	10	36	1	2.8	0.71	0.50
10	P	24	32	2	6.2	0.39	0.33
11	P	17	30	3	10.0	0.81	0.60
12	P	9	30	3	10.0	0.40	0.37
13	P	8	31	4	12.9	0.70	0.56
14	P	11	36	0	0.0		
15	P	8	30	0	0.0		
18	P	41	30	0	0.0		

[a] I = improvement cut; silvicultural thinning. P = partial cut; diameter-limit cut. C = clearcut.
[b] Time between harvest and sampling in 2004.

Time series of annual increment calculated using tree rings show that basal area growth of sprouts greatly exceeded that of trees from the study sites at similar ages (fig. 3A). Mean basal area of sprouts at age 10 was equal to mean basal area of trees currently in the overstory at age 28 and larger than understory trees of seed origin are likely to reach before at least age 80 (fig. 3B). However, it is important to remember that most of the largest trees were removed from the sites in diameter-limit cuts, so estimates of tree growth from the current overstory likely underestimate trees originating from seed in open-grown stands.

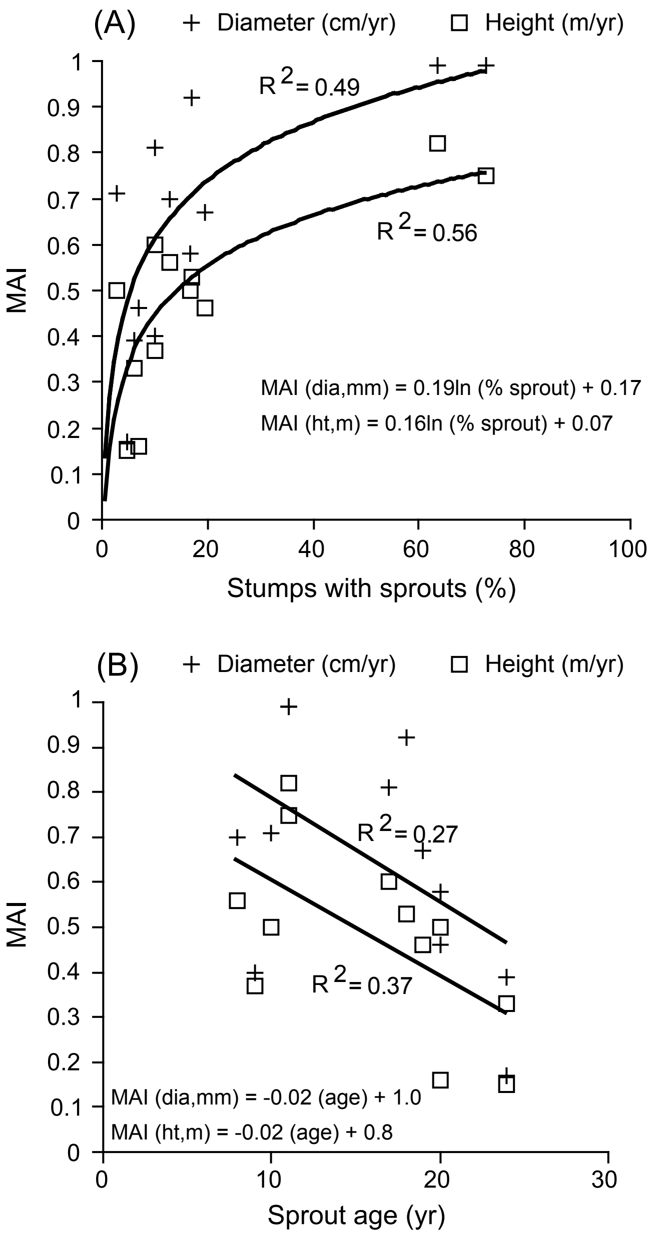

Figure 2—Relationship of baldcypress stump sprout mean annual growth increment (MAI) to stump sprout occurrence (A) and age (B).

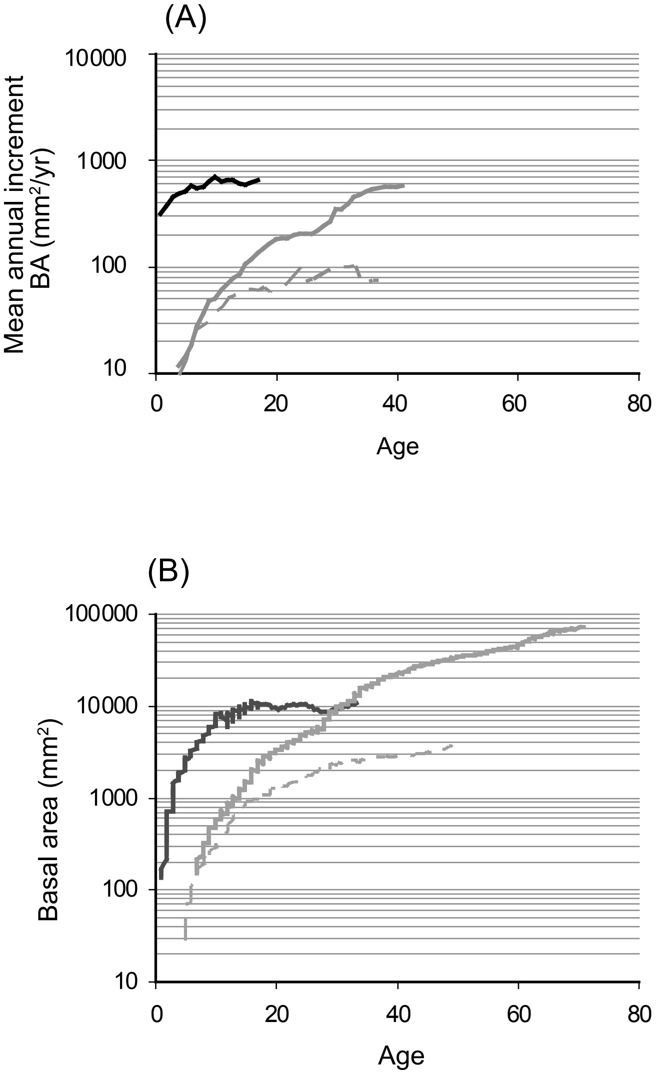

Figure 3—Study mean growth of stump sprouts (black line), overstory trees (solid gray line) and understory trees (dashed gray line) determined from tree ring analyses: (A) basal area mean annual increment; (B) basal area.

Most stumps were at least 40 cm in diameter (50 ± 14 cm) and nearly 1 m high (89 ± 26 cm). Within this narrow range of sizes, there were no strong relationships between characteristics of stumps and their sprouting. Bivariate correlation analysis did not reveal strong relationships between stump sprout survival or size and water depth or other site factors.

The condition of the live sprouts was highly variable. However most sprouts were present on stumps with poor callus tissue formation (wound-covering tissue), and many stumps had advanced decay. In many instances, decay was observed in the base of the sprouts themselves. The hollow nature of some sprouts, the narrow band of living tissue on stumps near sprouts, and the position of sprout-stump interface (usually about 1 m above the ground) suggested that some sprouts would likely not survive to be mature trees. In a few cases, almost the entire stump had callused over and, despite minor decay, the sprouts appeared likely to survive to become mature trees.

The number of baldcypress seedlings at each site ranged from 0 to 953 ha^{-1} (table 1). Seedlings at permanently flooded sites 1, 2, and 10 were rooted in unconsolidated, floating organic substrates, and we judged them to be ephemeral and unlikely to survive. Seedlings at sites 12, 16, and 17 were rooted in mineral substrates at sites with riverine flooding and may survive. We observed water tupelo seedlings only at sites 16 (44 ha^{-1}) and 17 (119 ha^{-1}). Overall, seedling regeneration was currently not sufficient for regeneration of any of the sites to baldcypress or water tupelo.

DISCUSSION

The proportion of baldcypress stumps with surviving sprouts did not change with age since cutting for the range of ages in our data (10 to 41 years). Also, our study-wide median of 10 percent sprout survival is comparable to the range of 0 to 23 percent survival across several sites in Louisiana at ages 4 to 7 reported by Conner (1988). Thus, it appears the mortality rate of sprouts after age 10 is low.

Low and spatially discontinuous sprout survival indicates stump sprouts cannot generally be considered sufficient to establish a new stand or to effectively enhance regeneration. However, this interpretation has several limitations. First, the diameter-limit cutting that dominated our sites is probably not suited to produce either coppice or seedling regeneration of baldcypress or water tupelo, because the amount of light reaching the ground often remained relatively low. Second, the trees cut were primarily sawtimber-sized baldcypress trees of relatively large diameter. Although we found no simple correlation between stump size and sprouting, large stumps have been found elsewhere to be less successful at producing vigorous sprouts compared to smaller stumps.

The high growth rates of sprouts up to age 20 suggests that surviving stump sprouts are capable of producing overstory trees. However, it is not clear whether decay originating in the stumps will allow large sprouts to remain wind firm. We saw no breakage of sprouts, but most sprouts in our study were not in a dominant or open-grown condition that would expose them to high winds.

The poor coppice regeneration and lack of seedlings across the sites suggests that successional processes will move species composition on many of the surveyed stands away from domination by baldcypress and water tupelo. If a site is not excessively flooded during the growing season, it will likely become dominated by shade-tolerant species (Conner and Day 1976). For example, red maple and ash appear poised to dominate the overstory of the somewhat drier survey sites, but with poor quality trees. Preferential harvesting of baldcypress or water tupelo without specific provisions for regeneration will likely accelerate species conversion. Diameter-limit cutting, which was the dominant harvest type on sites we visited, is therefore high-grading and a poor silvicultural practice. The preferred approach is group selection or clearcutting, possibly with preparatory cuts to establish advance regeneration (Meadows and Stanturf 1997, Wilhite and Toliver 1990). The permanent flooding on many of the sites may preclude any natural regeneration, regardless of silvicultural treatment. More research is needed to design effective silvicultural systems for these sites.

CONCLUSIONS

Regeneration from stump sprouting was insufficient to regenerate the surveyed stands, but mortality of sprouts appeared low after 10 years. Although surviving stump sprouts were vigorous, they were not regularly distributed within stands, and we found no variable to explain variation in stump sprout survival or vigor. The surveyed sites generally were not regenerating to baldcypress–water tupelo forest, either because diameter-limit cutting maintained an overstory sufficient to suppress seedling regeneration or because flooding prevented germination. Silvicultural prescriptions for baldcypress-water tupelo forests must therefore include plans for obtaining natural seedling or artificial regeneration.

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