

Regeneration and Growth After Logging Florida Pondcypress Domes

VALERY J. TERWILLIGER
KATHERINE CARTER EWEL

ABSTRACT. Recovery of vegetation after logging 16 small (1-5 ha), undrained pondcypress domes in north central Florida was analyzed. One dome was undisturbed and the others had been logged from a few months to 45 years before the study began. Densities of young (<2 yr old) pondcypress (*Taxodium distichum* var. *nutans* (Ait.) Sweet) were higher in domes that were recently logged than in older domes, whereas densities of other young woody plants were similar regardless of when a dome had been logged. Pondcypress saplings were significantly more abundant in domes logged 3 years before the study, and had sprouted after the domes were logged. There were no striking differences in canopy composition between older (15-45 yr) logged domes and historical descriptions of unlogged domes. In general, no differences in tree species composition (importance values, relative and absolute densities, frequencies and dominances of major species, and species diversity) were found among the domes. Also, selective logging did not result in a growth release among remaining trees. Over a period of 45 years or less, pondcypress domes appeared to recover their original basal area and dominance after selective logging and clearcutting. FOREST SCI. 32: 493-506.

ADDITIONAL KEY WORDS. *Taxodium distichum* var. *nutans*, recovery from logging.

SWAMPS dominated by pondcypress (*Taxodium distichum* var. *nutans* (Ait.) Sweet) in the southeastern United States coastal plain were first described as floristically and structurally discrete units by John Bartram (1769). While travelling through northeastern Florida, his son, William Bartram (1791) made one of the earliest references to the importance of cypress for wildlife, timber, and agriculture. Vernon (1947) used the term "dome" to describe these swamps because, in silhouette, they are dome-shaped: larger trees tend to be more centrally located and shorter trees occur around the edges. In north central Florida, domes occupy roughly circular, poorly drained depressions scattered throughout pine flatwoods and occasionally in mixed hardwood hammocks.

Although pondcypress domes occupy approximately 16 percent of Florida's commercial forest lands (Anonymous 1978), commercial use of pondcypress has been sporadic and slight. This is in part because large pondcypress trees often

At the time of this study, the authors were Graduate Assistant and Associate Professor, respectively, School of Forest Resources and Conservation, University of Florida, Gainesville, FL 32611. Ms. Terwilliger's current address is Department of Geography, University of California, Los Angeles, CA 90024. They thank Drs. R. Fisher and G. R. Best for critical input; Drs. D. Hall and R. Shaw as well as J. Easterday, J. Smith, J. Stenberg, and S. Terry for identifying plants; and, among others, M. Greenfield, B. Kersey, G. Lain, L. Parendes, B. Rushton, D. and S. Stewart, and C., F., and J. Terwilliger for field assistance. They also wish to thank the Gopher Ridge Headquarters of St. Regis Paper Company, Graham Headquarters of ITT Rayonier, Inc., and the staff at the Richloam Unit of the Withlacoochee State Forest for technical information, aerial photographs, block maps, and the use of their properties for research. Financial assistance was provided by the USDA Forest Service. This paper is University of Florida Agricultural Experiment Station Journal Series No. 6087. Manuscript received 6 December 1984.

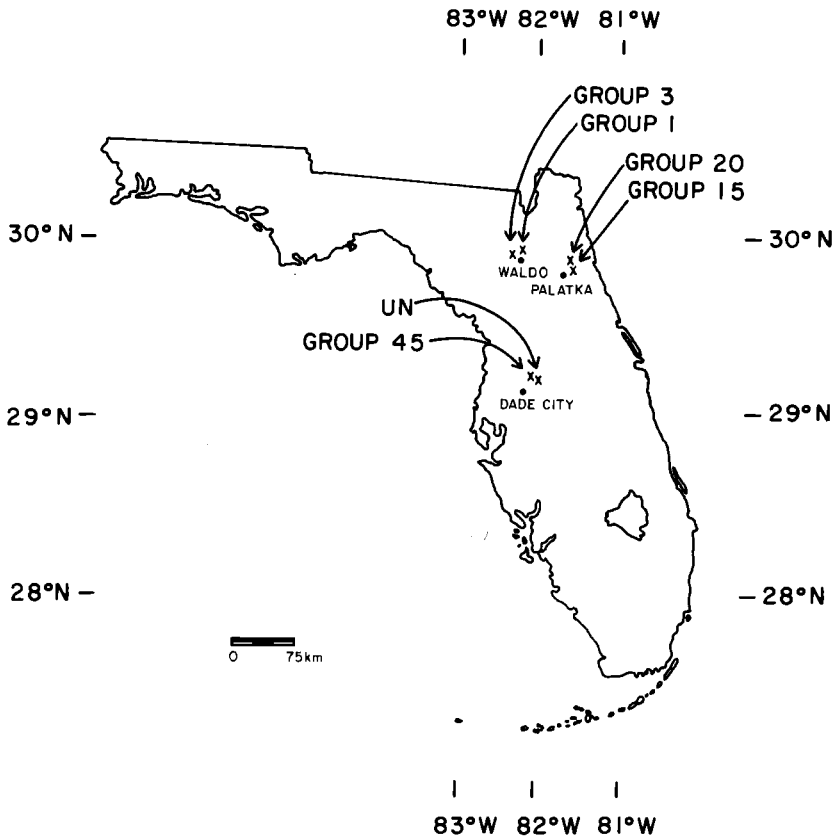


FIGURE 1. Locations of study areas.

have heart rot, and better quality timber species have been more abundant and accessible. Traditionally, pondcypress has been used for fence posts, stakes, and novelty items. However, its commercial uses are currently increasing to include mulch and pulp.

The pondcypress dome itself has value as an intact ecosystem. Water shortages and other environmental stresses, perhaps related to extensive elimination of wetlands in Florida, have stimulated interest in documenting these values (e.g., Ewel and Odum 1984). For instance, Harris and Vickers (1984) argue that the mosaic of pondcypress domes in a pine flatwoods landscape increases wildlife diversity. Consequently, the long-term effects of logging on these ecosystems must be examined in order to determine whether less tangible values may be diminished.

Domes have been extensively logged in Florida, and most now contain second growth trees. No silvicultural management practices have been systematically explored, although pondcypress plantations have been established in China from Florida seed (Kellison and others 1982). The objective of our research was to examine some long- and short-term effects of common logging practices on the floristic composition of small pondcypress domes and on their capacity to regenerate.

STUDY SITES

Sixteen small (1–5 ha) pondcypress domes were selected in north central Florida. The domes were grouped into six “age” groups according to the amount of time

TABLE 1. Classification of study domes and general characteristics. Group number designates approximate number of years since logging. Plantations and flatwoods are predominantly slash pine (*Pinus elliottii* Engelm).

Group	Logging treatment	Dome	Area (ha)	Maximum depth (cm)	Surrounding vegetation
1	Selective cut of large stems	A	0.8	48	Plantation <5 years.
		B	.8	63	Plantation <5 years.
		C	.8	81	Plantation <10 years.
3	Clearcut, seeded with slash pine	A	1.5	50	Plantation 15–20 years.
		B	2.5	65	Plantation 15–20 years.
		C	2.0	60	Plantation 15–20 years.
15	Selective cut of small stems	A	1.3	63	Plantation <5 years.
		B	1.3	23	Plantation <5 years.
		C	1.0	43	Plantation <5 years.
20	Selective cut of large stems	A	1.5	64	Plantation <5 years.
		B	1.3	46	Plantation <5 years.
		C	1.0	58	Plantation <5 years.
45	Selective cut of large stems	A	2.0	116	Flatwoods, mixed hardwood hammock.
		B	1.5	106	Flatwoods, mixed hardwood hammock.
		C	1.0	107	Flatwoods, large cleared areas.
UN	Undisturbed		5.3	79	Flatwoods, cypress/mixed hardwood swamp.

that had passed since they were logged (e.g., group 1 domes were logged one year before the study began, etc.) (Fig. 1). Only a single undisturbed dome could be located for the study (Table 1). The year a dome was logged was determined by conversations with foresters at each location and/or from sequential aerial photographs.

None of the domes had been drained or had berms surrounding them, and all showed evidence of recent fires. Logging practices depended upon accessibility of trees in a dome and commercial needs at the time of timber removal. The domes in groups 1, 20, and 45 were selectively logged for their larger stems, but small stems were selectively logged from the group 15 domes. Group 3 domes were clearcut in an effort to convert them to slash pine (*Pinus elliottii* Engelm.) plantations. Many stumps were removed from these domes, and the areas were aerially seeded with slash pine.

METHODS

VEGETATION SAMPLING

Vegetation was divided into four separate categories for inventory: trees, medium stratum plants, low stratum plants, and young plants. Trees were defined as woody plants greater than 3.0 cm in diameter. Diameter was measured at 46 cm above the buttresses of trees or 1.37 m above the ground for trees without buttresses. Medium stratum vegetation was defined as vegetation greater than 1 m tall with a diameter of less than 3.0 cm. Species of medium stratum size that also occurred as trees were subcategorized as saplings. Low stratum vegetation included all plants under 1 m tall. Young plants were defined as plants of woody species that were under 2 years of age, and were subcategorized as seedlings or vegetative sprouts.

Three parallel belt transects per dome were used to inventory trees. Each transect was 10 m wide by the length of the dome, and was composed of contiguous 5

m × 10 m cells. One transect bisected the center (point of lowest elevation) of the dome, one crossed a point midway between the dome center and edge, and the third transect was tangential to an edge of the dome. The same proportion (14 percent) of each dome was inventoried by randomly eliminating cells from shallow, medium, and deep parts of each transect.

Medium stratum plants were measured in nine of the tree inventory cells of each dome during May and June 1982 (Terwilliger 1983). Three of these cells were located along the 30 m central section of the central transect, and the other six cells were on parallel locations on the other two transects. Low stratum vegetation was inventoried in nine 1 m² quadrats. Each quadrat was placed at a random point within the cell that paralleled the long side of a medium stratum sample cell.

All young plants and the vegetative sprout subcategory were counted in the low stratum quadrats. Seedling sample cells were selected from the central transect: one at the center, one midway between the center and edge, and one at the edge. Young pondcypress plants were inventoried from the central transect of each dome after randomly eliminating cells where necessary to achieve a sample size of 6 percent of the dome's area.

VEGETATION ANALYSIS

Dominance, frequency, and density values were calculated for each tree species in every dome. Diameter measurements were converted to basal area and summed to calculate dominance. Species frequency was determined by dividing the number of cells in which that species was encountered by the total number of cells sampled in a particular dome. Species density was defined as the number of individuals of that species whose main trunk occurred within the cells of a dome that were sampled.

To obtain an importance value for each species, dominance, frequency, and density values were converted to relative values and summed according to the method described by Curtis and McIntosh (1951). The maximum importance value is 300. Relative densities were also used to calculate species diversity indices using the formula of Shannon and Weaver (1949).

Importance values of medium stratum species were calculated as above, but with the following modifications. Diameters were measured at 1 m. Stems with diameters ≤0.5 cm were assigned a value of 0.3 cm, stems with diameters 0.6–1.0 cm were assigned a value of 0.8 cm, and stems with diameters 1.1–1.5 cm were assigned a value of 1.3 cm. Importance values of low stratum species were calculated by summing only their relative densities and frequencies and could reach a maximum value of 200.

Plant species were identified either from voucher specimens or in the field with the assistance of Dr. David Hall, extension botanist, University of Florida Herbarium; Janet Easterday, University of Florida botany graduate student; Joel Smith, Dr. Robert Shaw, Steven Terry, and John Stenberg, (dendrologist, range management specialist, technician, and student, respectively, from the University of Florida School of Forest Resources and Conservation).

AGING PONDCYPRESS SAPPLINGS

Saplings in the medium stratum inventory plots of the group 3 domes were examined to indicate which tree species were likely to survive the seedling stage following logging and thereby to influence stand composition. To determine whether pondcypress saplings germinated before or after logging, ten saplings about 1 m in height were sampled in each of these domes. Two techniques were used to determine age. The first method involved counting the nodes around which

branchlets or branch scars were clustered. Green branchlets emanating from the uppermost node represent the most recent growth, and each successive node down the stem is an additional year's growth (G. R. Best, pers. comm. 1982).¹ Sapling ages were also determined by counting annual rings on a sanded, polished cross sectional slab using a microscope at 25×. A sapling's age was considered to be the older age resulting from the two techniques.

POND Cypress GROWTH FOLLOWING LOGGING

Growth rates of pondcypress trees were calculated to determine whether trees that remained in a dome after logging exhibited a growth release. A 5-mm diameter increment borer was used to extract cores from ten pondcypress trees in each of 13 domes. Cores were removed approximately 46 cm above the buttresses of the trees. Five of the trees were the largest in each dome and five were randomly selected from small to medium-sized trees. The three clearcut domes (group 3) had too few cypress trees large enough to core.

Approximate ages and annual growth increments were determined from the cores by counting and measuring their annual rings to the nearest 0.01 inch using a dissecting microscope at 25×. True annual rings have a solid line of almost flat, elliptical cells between one year's growth and the next. False rings are common in cypress and were distinguished from true rings by unevenness in sizes and shapes of cells along this boundary (Brown 1981). True ring widths were converted to basal area increments (BAI).

The post-logging growth rate of a tree was determined by calculating the relative basal area increment after 10 years.

$$BAI = \frac{A_{10} - A_0}{A_0}$$

where

- A_{10} = the basal area of a tree 10 years after its dome had been logged
- A_0 = the basal area of a tree at the time its dome was logged.

Relative rather than absolute growth rates were computed to compensate for initial differences in the basal area of trees at the time their domes were logged. These post-logging growth rates were determined for the cores from groups 15, 20, and 45. To account for the effects of age on growth rates, BAI's were divided into 10 categories according to the age of the tree at the time its dome was logged. The youngest category included trees 10–19 yr when their dome was logged; the next included trees 20–29 yr, etc. The tenth age category included all trees over 100 yr at logging time.

Since group 1 domes had been logged too recently to exhibit any significant change in growth pattern due to logging, their cores were analyzed with cores of the undisturbed dome to determine control growth rates (i.e., growth rates in the absence of logging). To establish control growth rates that could be compared to growth rates of each post-logging age class we first assumed that the mean age of trees in each post-logging age class was the midpoint of the range of the age category (e.g., 15 yr for the 10–19 yr category, 25 yr for the 20–29 yr category, etc.). We then established control growth rates from control cores (i.e., from group 1 and undisturbed domes) by calculating BAI values for the 10 yr period following the mid-point of each age category. The control growth rates were compared with post-logging growth rates for trees that were in corresponding age categories when their domes were logged; e.g., BAI's for trees that were in the 10–19 yr age category

¹ Best, G. R. 1982. Center for Wetlands, University of Florida, Gainesville, Fla. Personal communication.

when their domes were logged were compared with the BAI's for 15-yr old "control trees."

The possibility of confounding growth rates resulting from logging with growth rates influenced by periods of notably different climatic characteristics was minimized by the following procedure. One hundred years of monthly mean temperature and monthly total precipitation values from local federally operated weather stations (Kissimmee, Orlando, and Jacksonville) (U.S. Weather Bureau 1931, Weather Bureau 1953, NOAA 1953-79) were grouped by decades. Anomalous climatic periods were defined as those decades that differed in temperature and rainfall from other decades (by ANOVA, LSD analysis at $P \leq 0.05$). Growth rate data from climatically dissimilar periods were then eliminated from further analysis.

HYDROLOGY

Staff gauges were placed in the deepest part of each dome, and water depths (± 0.5 cm) were recorded every 2 weeks from January to June 1982, a period that included the winter wet season. Mean water depth was calculated.

Statistical Analysis

Differences in characteristics of vegetation composition between logging age groups were analyzed with the Kruskal-Wallis one-way analysis of variance and Mann-Whitney U tests at a 5 percent confidence level. Additional details on the results of specific tests may be found in Terwilliger (1983).

RESULTS

VARIATION IN TREE COMPOSITION

Pondcypress had the highest tree importance value in 13 domes (Table 2). Most frequently, slash pine had the second highest importance value in these domes. In the remaining three domes (1B, 3A, 20C), pondcypress was second to blackgum (*Nyssa sylvatica* var. *biflora* (Walt.) Sarg).

When importance, absolute density, and basal area of pondcypress, blackgum, and slash pine, and tree species diversity were compared among logging age groups, significant differences were found only for pondcypress basal area, which increased from more recently logged domes in groups 1 and 3 to the older domes in groups 15-45 (Fig. 2).

Relationships between mean water depth and importance of pondcypress, blackgum, and slash pine, and canopy species diversity were examined by the Maximum R^2 Improvement Technique (Ray 1982) using values from the domes that were logged more than 4 years ago. The only significant relationship was between mean water depth and tree diversity ($r = 0.64$, $P < 0.05$).

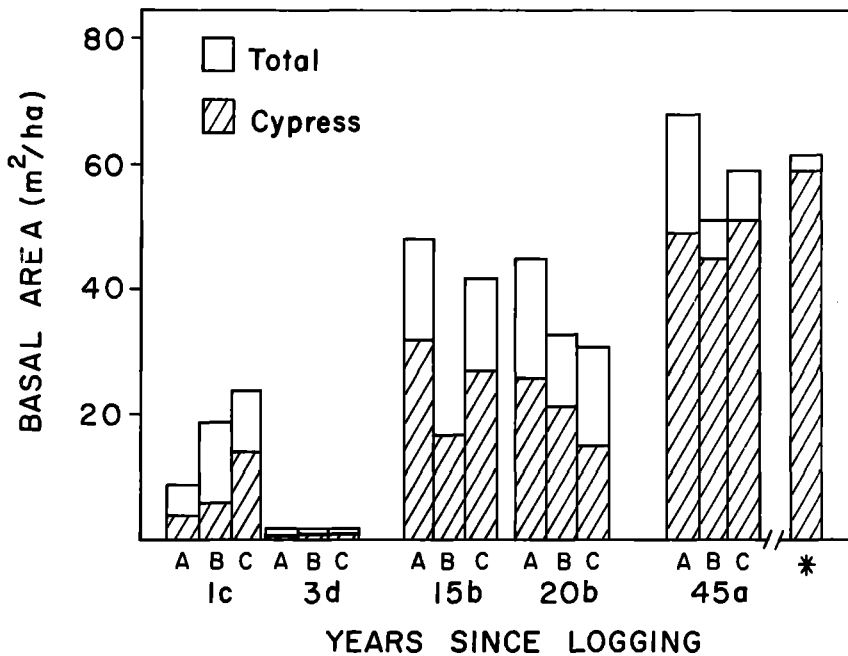
VARIATION IN MEDIUM AND LOW STRATA VEGETATION

None of the medium stratum species identified was present in every dome. Wax myrtle (*Myrica cerifera* L.), pondcypress saplings, and fetterbush (*Lyonia lucida* (Lam.) Koch) were the most ubiquitous species. Fetterbush had the highest importance value in the largest number of domes. Of the low stratum species, only Virginia chain fern (*Woodwardia virginica* (L.) J. E. Smith) was found in all sixteen domes. In half of the domes, it also had the highest importance value. Significant differences were found in densities of medium stratum plants between the logging age groups but they were not related to the time that had passed since logging.

Tree density, frequency, basal area, mean water depth, and water level fluctua-

TABLE 2. Importance values of major trees species and diversity index (H') in each study dome. Only species with an importance value of at least 20 in one or more domes are shown, although all tree species inventoried were used to calculate diversity.

Species	Logging age group and dome															UN	
	1			3			15			20			45				
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
<i>Acer rubrum</i>	—	14	—	5	7	2	3	—	—	—	1	—	12	4	14	4	24
<i>Fraxinus caroliniana</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	21
<i>Ilex cassine</i>	—	—	—	14	—	—	1	—	—	—	—	2	9	45	4	5	3
<i>Ilex myrtifolia</i>	67	46	27	40	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Myrica cerifera</i>	6	16	20	3	51	20	13	—	21	3	6	24	24	36	29	42	2
<i>Nyssa sylvatica</i> var. <i>biflora</i>	47	94	86	112	2	57	20	—	14	12	4	108	15	7	25	19	—
<i>Persea borbonia</i> var. <i>pubescens</i>	32	19	—	16	15	2	—	4	2	6	7	3	2	—	—	—	1
<i>Pinus elliotii</i>	67	41	18	33	86	23	96	6	108	113	114	4	11	9	10	1	—
<i>Taxodium distichum</i> var. <i>mutans</i>	81	71	149	64	133	189	165	291	150	134	162	90	154	189	179	172	—
H'	1.54	1.82	1.13	1.7	1.36	0.94	0.9	0.13	1.02	1.26	0.98	1.71	1.49	1.19	1.31	1.73	—



* UNLOGGED

FIGURE 2. Basal area in 16 pondcypress domes. Groups with the same lowercase letters are not significantly different ($P < 0.05$).

tion were examined by the Maximum R^2 Improvement Technique for association with medium and low strata plant densities. Of these, tree frequency had a significant negative relationship and mean water level had a significant positive relationship with medium stratum plant densities in the domes ($r = 0.7$, $P \leq 0.01$). Low stratum plant densities were inversely related to the logarithm of mean water depths ($r = -0.86$, $P \leq 0.01$).

REGENERATION

No young plants were abundant in the low stratum quadrats. Swamp bay (*Persea borbonia* var. *pubescens* (Pursh) Little) was the most ubiquitous tree species in the seedling sample cells (Table 3). Although blackgum was the only species to have higher importance values as a tree than pondcypress, its seedlings were found in only a few domes and were rare when found. Slash pine, which had tree importance values approaching those of pondcypress in some domes, was found as a seedling in more domes than pondcypress. Overall, the undisturbed dome had a much higher density of seedlings than the other domes.

In plots that were examined specifically for young pondcypress, densities of these plants were significantly higher in the more recently logged domes (groups 1 and 3) than in the other domes (Fig. 3). Vegetative sprouts of cypress were also common in a group 45 dome, but this was in response to a recent fire.

The Maximum R^2 Improvement Technique was used to determine which parameters (tree density, frequency, and basal area; medium and low stratum plant densities; mean water depth) that vary among the logging age groups might best explain the distribution of young pondcypress plants. Densities of pondcypress

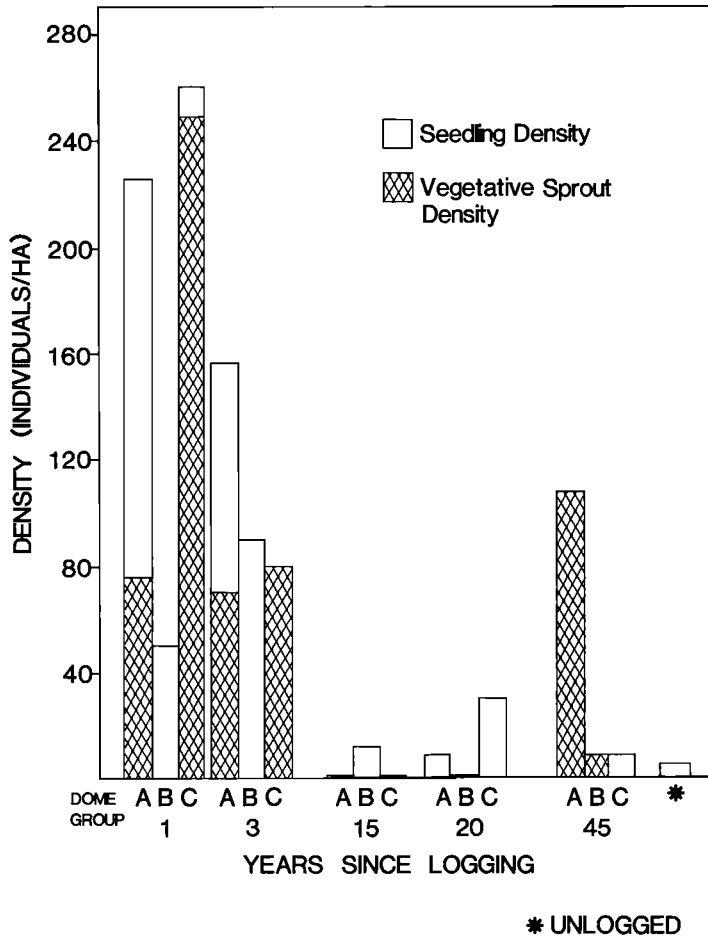


FIGURE 3. Densities of young pondcypress seedlings and sprouts in 16 pondcypress domes.

TABLE 3. Mean density (individuals/ha) of tree seedlings in 16 pondcypress domes. Each value is the mean of 3 domes except UN, which represents 1 dome.

Species	Logging age group					UN
	1	3	15	20	45	
<i>Acer rubrum</i>	7	—	—	15	37	6,467
<i>Fraxinus caroliniana</i>	—	—	—	44	—	—
<i>Gordonia lasianthus</i>	52	30	22	44	—	—
<i>Liquidambar styraciflua</i>	—	—	—	—	—	622
<i>Nyssa sylvatica</i> var. <i>biflora</i>	15	7	—	—	—	—
<i>Persea borbonia</i> var. <i>pubescens</i>	304	193	7	30	—	111
<i>Pinus elliotii</i>	7	7	15	52	44	—
<i>Quercus hemisphaerica</i>	—	—	—	7	22	156
<i>Quercus nigra</i>	52	—	—	—	22	—
<i>Taxodium distichum</i> var. <i>nutans</i>	37	44	—	—	—	—
<i>Ulmus americana</i> var. <i>alata</i>	—	—	—	—	—	1,556

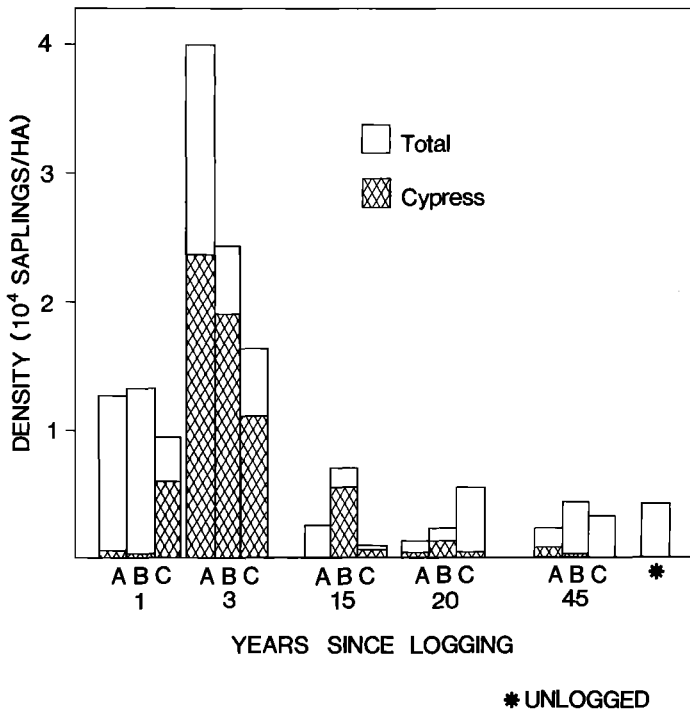


FIGURE 4. Densities of saplings in 16 pondcypress domes.

seedlings and sprouts combined were negatively related to tree basal area and positively related to mean water depth ($r = 0.7$, $P < 0.01$). Densities of seedlings alone were inversely related to tree, medium stratum, and low stratum densities ($r = -0.89$, $P \leq 0.005$).

None of the pondcypress saplings examined in the group 3 domes was older than 5 years, and at least 70 percent had germinated since logging. Two of the saplings were sprouts; the remaining had germinated from seeds. Sapling densities in group 3 domes were significantly higher than in the other thirteen domes ($P < 0.05$) (Fig. 4). There was no significant difference in the densities of non-pondcypress saplings between group 3 and other domes, however. Within the group 3 domes, pondcypress sapling densities were significantly higher than the densities of all other saplings combined.

PONDYPRESS GROWTH RESPONSE TO LOGGING

The pondcypress trees that were cored ranged in age from 34 to 186 years. Relative growth rates of pondcypress trees that remained in the domes after logging were significantly higher ($P < 0.05$) in the 20–29 year and 80–89 year age classes than growth rates of control trees at corresponding ages. No other differences were observed.

DISCUSSION

EFFECTS OF LOGGING ON SPECIES REGENERATION IN DOMES

Waterlogged, periodically flooded soils are hostile sites for the establishment and survival of most trees. However, pondcypress will exist as an almost pure stand in domes with high water levels (Broadfoot and Williston 1973, Loucks and Keen

1973). The degree of importance of pondcypress in a dome appears to be partly due to its superior ability to compensate for the limiting effects of a periodically inundated, anaerobic environment (Mattoon 1916, Hook and Scholtens 1978). For instance, pondcypress seeds will remain viable after being submerged for a year (Applequist 1959), and pondcypress germination success improves if the hydroperiod is long enough to soften the hard seed coats (Murphy and Stanley 1975). Seeds of possible competitors such as blackgum will remain viable following several months of submergence, but not a full year (Briscoe 1957). Neither pondcypress nor blackgum seeds will germinate under water, however (Shunk 1939, Debell and Naylor 1972). Slash pine seeds are not likely to germinate unless they land on suitably aerated soil, and slash pine survival on wet soils is generally poor (Pritchett 1979, Shiver and Forston 1979). Pondcypress seed germination (Mattoon 1916), seedling height growth (Demaree 1932, Dickson and Broyer 1972, Loucks and Keen 1973), and increase in tree biomass (Mitsch and Ewel 1979, Brown 1981) are best on moist but not flooded soil, but these are favorable sites for the establishment of more mesic species as well.

Crowding or shading by vegetation (e.g., shrubs, Maki and others 1980; herbs, Gunderson 1977; general light availability, Browder and others 1974) has been found to reduce seedling establishment of baldcypress (*Taxodium distichum* (L.) Rich.). The inverse relationship of pondcypress seedling densities to tree, medium (shrub), and low (herb) strata plant densities in our study domes suggests that crowding or shading may inhibit pondcypress establishment as well.

Logging was associated with higher cypress seedling and sprout establishment rates in our study sites. The densities of young pondcypress were significantly higher in the more recently logged (<4 yrs ago) domes than in the older domes. No significant differences were found in densities of other young woody species between more and less recently logged domes. A partial explanation for this association may be that reduced crowding or shading by logging improves conditions for pondcypress establishment, but saturated soil conditions continue to limit the establishment of other species. Our findings provide some support for this explanation because study domes with the highest young plant densities tended to have the deepest water and lowest tree basal areas.

Pondcypress sapling densities were highest in the group 3 domes, and many of these saplings had germinated after logging. The densities of pondcypress saplings were significantly higher than the densities of non-pondcypress saplings in these three domes in spite of treatments to convert the areas to slash pine plantations. This suggests that the survival of pondcypress germinants was good for several years following logging.

EFFECTS OF LOGGING ON GROWTH RATES AND SPECIES COMPOSITION

Cambial growth in mature pondcypress increases in response to nutrient inputs, such as secondary sewage effluent (Brown 1981, Nessel and others 1982, Lemlich and Ewel 1985). Marois and Ewel (1983) reported increased growth rates in some pondcypress domes in which water levels had been lowered. In a larger swamp, thinning accelerated baldcypress growth rates without appreciably affecting associated hardwoods (McGarity 1979). Our study showed that two age classes of pondcypress trees from logged domes grew faster than control trees from unlogged domes. However, these age classes were unrelated to each other and there is no apparent ecological or physiological explanation for the response. It must therefore be concluded that growth rates were independent of logging. Phipps (1979) concluded that the limiting effects of the hydrologic conditions of swamps may mask the influence of logging on stand growth rates; this may also be the case in the pondcypress domes that we studied.

Logging does not appear to have permanently altered tree composition of pondcypress domes. Pondcypress basal area and dominance increased steadily after logging, suggesting that pondcypress may regain previous dominance levels. Importance values, densities, and basal areas of other major species did not differ among logging age groups, suggesting no relationship between logging and encroachment of other species in these small swamps.

Harper's (1914) early descriptions of the vegetation characteristic of undisturbed domes in north central Florida provide a qualitative basis of comparison for the study domes. He listed pondcypress, blackgum, slash pine, and myrtle-leaved holly (*Ilex myrtifolia* Walt.) as the major tree species. He also observed that pondcypress was always the most abundant tree, blackgum occasionally approached pondcypress in abundance, and the other two species were far less abundant than pondcypress. Wright and Wright (1932) listed sweetbay (*Magnolia virginiana* L.), swamp bay, loblolly bay, (*Gordonia lasianthus* (L.) Ellis), and water oak (*Quercus nigra* L.) as less abundant species common to most domes in the Okefenokee Swamp.

Only a few deviations from these early general descriptions were present in the tree composition of the study domes. In dome 20C, blackgum had a higher relative density and importance than pondcypress. Until 2 years before the study, this dome had been surrounded by a large blackgum-pondcypress-mixed hardwood swamp. The undisturbed dome (UN) had similar surroundings, yet pondcypress in that dome had a far higher importance value (172) than blackgum (19). Available seed, soil water conditions following logging or inherent differences in the longevity of each species may account for these differences in species dominance between dome 20C and the undisturbed dome, although the importance values of these two species prior to logging are unknown. Except in the more recently logged domes, 20C was the only dome in which a tree species had a higher importance value than pondcypress.

Domes 15A and C and domes 20A and B had very high slash pine importance values. These domes, like some of the others, had been surrounded by slash pine flatwoods. However, domes with high slash pine importance values were much shallower and were dry longer than all but one of the other domes surrounded by slash pine. In that dome (15B), almost all of the trees had burn scars 2–3 m high, suggesting that slash pine establishment may have been limited by fire.

These results suggest that, unlike baldcypress (Gunderson 1977), natural re-establishment rates of pondcypress are high. Because pondcypress is found in swamps with longer hydroperiods and less nutrient inflow than are found in baldcypress swamps, and it is associated with fewer potential co-dominants, the probability of significant change in species composition in an undrained swamp is apparently slight. It seems unlikely, therefore, that common pondcypress logging practices will result in extreme permanent ecosystem alterations.

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Forest Sci., Vol. 32, No. 2, 1986, pp. 506-511
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Benomyl Root Treatment Controls Brown-Spot Disease on Longleaf Pine in the Southern United States

A. G. Kais, C. E. Cordell, and C. E. Affeltranger

ABSTRACT. Root systems of longleaf pine seedlings, *Pinus palustris* Mill., were wetted and then coated with various benomyl/kaolin (clay) mixtures (0 to 20 percent a.i. benomyl) prior to seedlings being outplanted on sites in Louisiana, Mississippi, Alabama, Georgia, and Florida. Survival, percent brown-spot needle blight infection (caused by *Scirrhia acicola* (Dearn.) Siggers), and growth were evaluated annually for 3 years following planting. Seedling survival generally decreased in a west to east gradient. Survival also decreased with increased benomyl levels at all sites. Interactions of survival and levels of benomyl with measured soil properties were investigated. For increased benomyl levels there was a negative correlation of survival with increased percentage of sand in the soil and a positive correlation of survival with increased levels of silt in the soil. Benomyl root treatments provided effective brown-spot disease control during the 3-year period, which in turn stimulated rapid height growth. A 5 percent a.i. benomyl/kaolin mixture is recommended for root treatment over the natural range of longleaf pine in the southern United States. *FOREST SCI.* 32:506-511.

ADDITIONAL KEY WORDS. *Scirrhia acicola*, systemic fungicide, soil texture, rapid height growth, *Pinus palustris*.

BROWN-SPOT NEEDLE BLIGHT, caused by *Scirrhia acicola* (Dearn.) Siggers, is the most important disease of longleaf pine, *Pinus palustris* Mill., seedlings in the South. This disease causes defoliation, reduces plant vigor, and frequently causes mortality. Repeated defoliation coupled with reduction of seedling vigor extends the grass stage of longleaf pine. This delays and may prevent the initiation of height growth (Siggers 1932, Wakeley 1954).

Historically, nursery seedbeds and seed orchard trees have been protected from brown-spot infection by fungicidal sprays using either Bordeaux mixture or ferbam (Fermate®) (Derr 1957, Siggers 1944, Wahlenberg 1946). Chlorothalonil (Daconil® or Bravo®) has also been recommended for brown-spot control (Phelps and others 1978, Skilling and Nicholls 1974, Kais 1975). However, the use of any of these three fungicides in field plantings require anywhere from four to seven applications annually for up to 4 years. Recent reports have indicated that the use of benomyl (Benlate®), a systemic fungicide,

The authors are, respectively, Principal Plant Pathologist, USDA Forest Service, Forestry Sciences Laboratory, Box 2008 GMF, Gulfport, MS 39505; Pathologist, USDA Forest Service, State & Private Forestry, Asheville, NC 28803; and Pathologist, USDA Forest Service, State & Private Forestry, Alexandria, LA 71360. Mention of a company or trade name does not imply endorsement by the U.S. Department of Agriculture. Manuscript received 14 March 1984.