Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part IV--Pitch Pine (*Pinus rigida* Mill.)

by
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INTRODUCTION

This report is the fourth in a series covering the wood density surveys of the minor species of yellow pine in the Eastern United States.[1] Literature review and historical information regarding these surveys were presented in "Part I—Spruce Pine (*Pinus glabra* Walt.)" by Taras and Saucier (1968) and will not be repeated here.

The objectives of the survey were:

(1) To obtain data that will provide an estimate of the average specific gravity of unextracted and extracted wood of each minor species, and establish the degree of variation about each mean.

(2) To evaluate increment core/tree specific gravity relationships and develop regression equations for predicting tree specific gravity from increment core specific gravity.

(3) To examine the geographic trends of wood specific gravity within the range of each species, from east to west and from north to south.

[1]This study was conducted in cooperation with the Forest Products Laboratory, the Northeastern Forest Experiment Station, the Southern Forest Experiment Station, and state forestry services, the pulp and paper industries, the southern pine plywood and sawmill industries, and numerous private forest owners throughout the Southern and Eastern United States.

MATERIALS AND METHODS

Species

Pitch pine (*Pinus rigida* Mill.) grows over a wide geographic range, from central Maine south to western Virginia, to eastern Ohio, locally in eastern Kentucky and Tennessee, and in the mountains of North Carolina, South Carolina, and Georgia (fig. 1). Pitch pine is a tree of great diversity in form, habit, and development. In New England it is a small tree commonly found in the coastal districts and river valleys in company with gray birch (*Betula populifolia* Marsh.). In southern New Jersey it is a short, poorly formed tree found on excessively drained, sandy, sterile soils with scrub oak (*Quercus ilicifolia* Wangenh.). South through the Appalachian Mountains to northern Georgia, pitch pine of commercial importance grows at elevations between 1,400 to 4,500 feet. It often occurs in pure stands or with Table-Mountain pine (*Pinus pungens* Lamb.) on the drier southern slopes. Pitch pine reaches its best development (50 to 60 feet in height and 1 to 2 feet d.b.h.) in mixed hardwood stands where it is less tolerant than its associates—blackgum, red maple, various oaks, and hickories (fig. 2A). The largest living pitch pine measures 37.9 inches d.b.h. and is 91 feet tall (Pomeroy and Littlecott 1967).

The needles of pitch pine are 3 to 5 inches long, yellowish-brown, rigid, usually somewhat twisted, and occur in fascicles of

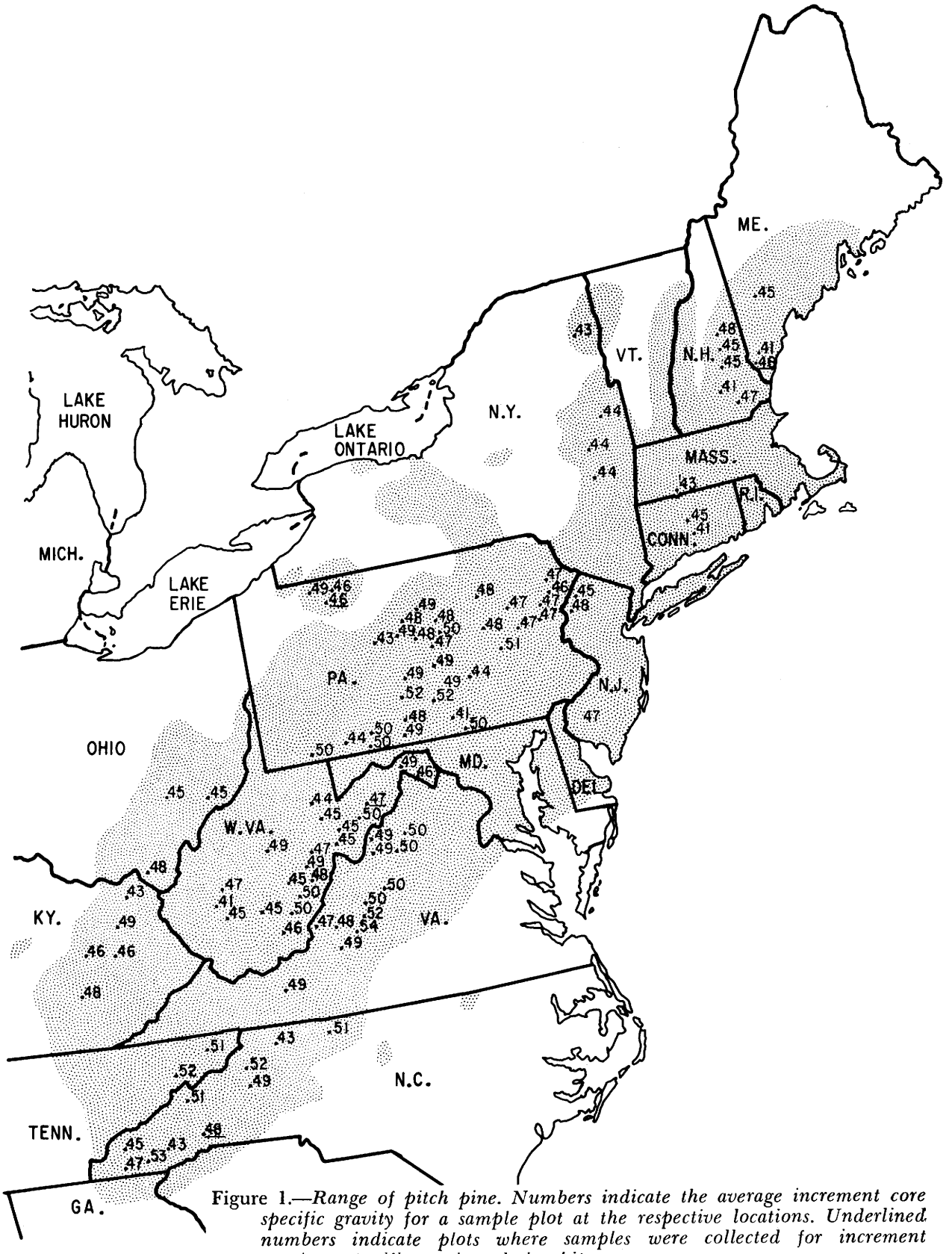

Figure 1.—*Range of pitch pine. Numbers indicate the average increment core specific gravity for a sample plot at the respective locations. Underlined numbers indicate plots where samples were collected for increment core/tree specific gravity relationships.*

three (fig. 2B). Cones are 2 to 3½ inches long, nearly sessile, ovoid, and usually persist for many years (fig. 2C). The cone scales are stiff and armed with a rigid prickle. The scientific name *rigida*, meaning stiff or rigid, refers to the cone scales. The bark on young stems is dark and scaly (fig. 2D); bark of mature trees is 1 to 2 inches thick at the base and forms smooth, flat, yellowish-brown plates separated by narrow, irregular fissures (Harlow and Harrar 1950).

Field Sampling Procedure

To meet the objectives of the study, 100 plots were sampled throughout the range of pitch pine. We calculated the number of trees sampled per plot had to be 20, in order to obtain an estimate of the mean specific gravity with a 95 percent confidence interval width of .02. The plots were selected randomly, with replacement, with the probability roughly proportional to the commercial forest area within Forest Survey Units[2] containing pitch pine. A 6-mile grid system was used to locate plots randomly within survey units.

At each plot location, a random azimuth was selected along which the first 20 trees, over 5.0 inches d.b.h. and showing no signs of heartrot, were sampled by removing two increment cores from opposite sides of each tree. The total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were recorded.

The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at four locations within the range of pitch pine (fig. 1). Two increment cores were taken from each of 25 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

Laboratory Procedures

The specific gravity of all unextracted and extracted increment cores was determined by the maximum moisture method described by Smith (1954). The specific gravity of wood disks was determined by the buoyancy method (Heinrichs 1954) and is based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. Extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. Following extraction the cores were saturated with water, and their specific gravity was determined by the maximum moisture method. No wood disks were extracted.

The increment cores from the trees collected to analyze increment core/tree specific gravity relationships were each divided into three equal parts, and the specific gravity of each segment was determined. The purpose was to obtain a weighted increment core specific gravity and to examine the relationship of parts (1/3 or 2/3) of whole increment cores to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravities of segments by the cross-sectional areas the segments represented.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Pitch Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* pitch pine was .474, based on the average of two whole increment cores from 2,000 sample trees collected over the entire range of the species. The standard error of the mean increment core specific gravity was .001, and the standard deviation about the mean of the individual observations was .047.

The average specific gravity of *extracted* increment cores was .435; standard error was .001, and standard deviation of individuals was .035. The average specific gravity of unextracted and extracted increment cores by individual sample plots is shown in table 1. Table 1 also includes the average

[2]Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

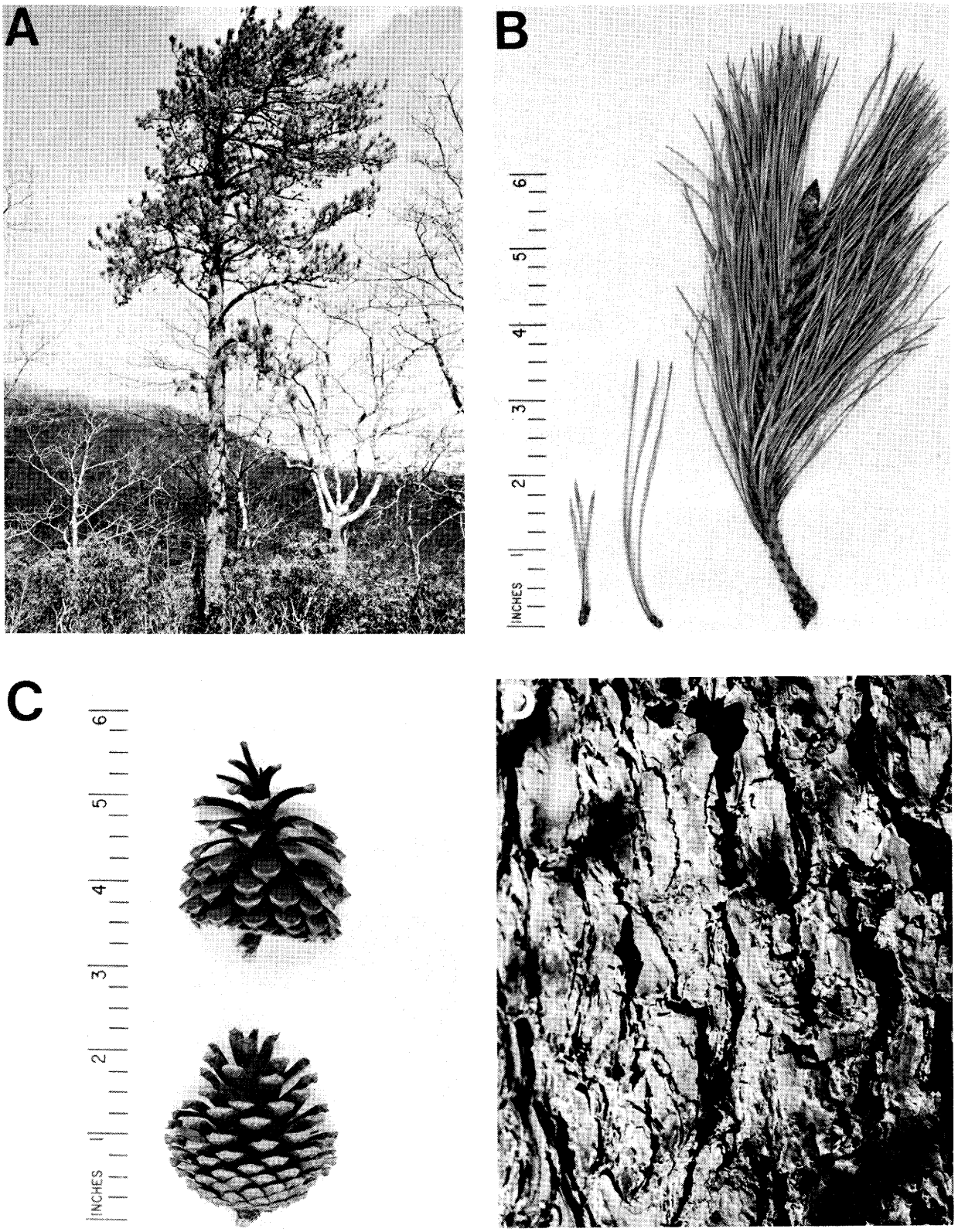

Figure 2.—*Botanical features of pitch pine*: (*A*) *mature tree*, (*B*) *needles*, (*C*) *cones*, (*D*) *bark of young tree*.

Table 1.—*Specific gravity of unextracted and extracted increment cores from pitch pine*

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
1	Oxford, Me.	20	12.0	59	.451 (.007)	.030	.417 (.007)	.032	8.15
2	York, Me.	20	8.8	38	.412 (.007)	.030	.318 (.004)	.019	29.56
3	Carroll, N. H.	20	9.9	63	.475 (.009)	.040	.423 (.006)	.026	12.29
4	Carroll, N. H.	20	10.4	45	.446 (.010)	.044	.392 (.006)	.027	13.78
5	Belk Nap, N. H.	20	11.2	63	.454 (.008)	.036	.403 (.006)	.025	12.66
6	Merr Mack, N. H.	20	12.6	46	.405 (.010)	.044	.363 (.008)	.035	11.57
7	Rockingham, N. H.	20	12.5	73	.467 (.014)	.061	.413 (.009)	.041	13.08
8	Hamden, Mass.	20	8.2	32	.430 (.006)	.026	.403 (.006)	.028	6.70
9	Hartford, Conn.	20	10.1	52	.455 (.008)	.034	.417 (.007)	.030	9.11
10	Middlesex, Conn.	20	8.9	32	.408 (.005)	.024	.383 (.005)	.020	6.53
11	Essex, N. Y.	20	8.9	41	.431 (.010)	.045	.393 (.007)	.030	9.67
12	Washington, N. Y.	20	9.2	48	.445 (.009)	.039	.404 (.006)	.025	10.15
13	Schenectady, N. Y.	20	9.8	39	.443 (.007)	.030	.399 (.004)	.018	11.03
14	Albany, N. Y.	20	9.6	43	.436 (.010)	.043	.404 (.007)	.032	7.92
15	Sussex, N. J.	20	6.7	49	.454 (.006)	.027	.429 (.006)	.028	5.83
16	Salem, N. J.	20	10.1	48	.467 (.009)	.038	.438 (.004)	.019	6.62
17	Pike, Pa.	20	11.9	66	.455 (.013)	.056	.416 (.007)	.033	9.38
18	Pike, Pa.	20	15.1	97	.473 (.006)	.026	.430 (.007)	.029	10.00
19	Pike, Pa.	20	11.3	73	.470 (.008)	.037	.428 (.007)	.029	9.81
20	Carbon, Pa.	20	7.7	53	.465 (.010)	.043	.425 (.009)	.041	9.41
21	Monroe, Pa.	20	7.8	47	.472 (.010)	.043	.430 (.006)	.026	9.77
22	Sussex, N. J.	20	11.6	101	.479 (.007)	.032	.435 (.009)	.038	10.11
23	Sullivan, Pa.	20	10.0	84	.478 (.007)	.031	.431 (.007)	.031	10.90
24	Luzerne, Pa.	20	9.1	80	.473 (.008)	.035	.433 (.009)	.040	9.24
25	Columbia, Pa.	20	8.8	60	.476 (.009)	.039	.417 (.008)	.038	14.15
26	Schuylkill, Pa.	20	9.9	74	.505 (.009)	.038	.451 (.007)	.030	11.97
27	Dauphin, Pa.	20	9.7	43	.444 (.008)	.035	.408 (.007)	.029	8.82
28	Clinton, Pa.	20	11.0	83	.503 (.014)	.060	.453 (.008)	.035	11.04
29	Clinton, Pa.	20	12.7	80	.473 (.007)	.032	.449 (.004)	.016	5.35
30	Clinton, Pa.	20	11.0	70	.478 (.012)	.054	.439 (.009)	.039	8.88
31	Clinton, Pa.	20	9.5	76	.489 (.005)	.023	.444 (.004)	.017	10.14
32	Clinton, Pa.	20	9.9	74	.478 (.010)	.043	.455 (.008)	.037	5.05
33	Clinton, Pa.	20	11.5	78	.482 (.006)	.027	.460 (.007)	.030	4.78
34	Clinton, Pa.	20	14.3	113	.490 (.007)	.029	.453 (.007)	.030	8.17
35	Clinton, Pa.	20	8.2	40	.427 (.007)	.031	.410 (.005)	.023	4.15
36	Mifflin, Pa.	20	10.7	110	.490 (.006)	.027	.453 (.006)	.027	8.17
37	Huntington, Pa.	20	13.7	96	.486 (.009)	.038	.444 (.008)	.037	9.46
38	Huntington, Pa.	20	14.9	100	.516 (.009)	.040	.462 (.009)	.038	11.69
39	Fulton, Pa.	20	9.2	71	.495 (.009)	.042	.446 (.006)	.025	10.99
40	Fulton, Pa.	20	9.7	53	.477 (.009)	.040	.442 (.007)	.029	7.92
41	McKean, Pa.	20	11.3	74	.465 (.008)	.034	.438 (.007)	.032	6.16
42	McKean, Pa.	20	10.7	66	.485 (.013)	.058	.437 (.005)	.023	10.98
43	Bedford, Pa.	20	8.1	49	.497 (.010)	.045	.452 (.007)	.031	9.96
44	Perry, Pa.	20	13.8	101	.486 (.009)	.040	.438 (.007)	.033	10.96
45	Perry, Pa.	20	11.8	91	.518 (.007)	.032	.477 (.006)	.028	8.60
46	Adams, Pa.	20	9.2	79	.503 (.008)	.036	.471 (.007)	.030	6.79
47	Adams, Pa.	20	9.9	66	.510 (.008)	.034	.462 (.005)	.021	10.39
48	Bedford, Pa.	20	11.5	92	.496 (.008)	.036	.437 (.005)	.023	13.50
49	Berkeley, W. Va.	20	8.5	37	.457 (.011)	.050	.409 (.005)	.022	11.74
50	Morgan, W. Va.	20	11.1	61	.485 (.006)	.028	.454 (.006)	.029	6.83
51	Hardy, W. Va.	20	9.0	62	.498 (.011)	.049	.446 (.008)	.034	11.66
52	Page, Va.	20	9.4	66	.504 (.007)	.033	.463 (.007)	.033	8.86
53	Page, Va.	20	10.9	63	.497 (.014)	.064	.447 (.005)	.022	11.19
54	Page, Va.	20	8.5	41	.487 (.010)	.045	.455 (.008)	.035	7.03
55	Botetourt, Va.	20	11.7	72	.537 (.009)	.038	.488 (.006)	.029	10.04
56	Rockbridge, Va.	20	11.5	67	.527 (.009)	.041	.486 (.008)	.035	8.44
57	Rockbridge, Va.	20	9.4	59	.501 (.012)	.053	.454 (.006)	.028	10.35
58	Rockbridge, Va.	20	9.5	58	.479 (.007)	.033	.440 (.006)	.025	8.86
59	Botetourt, Va.	20	9.3	75	.491 (.007)	.033	.456 (.008)	.034	7.68
60	Pulaski, Va.	20	8.1	42	.469 (.008)	.034	.429 (.007)	.033	9.32
61	Alleghany, Va.	20	8.1	58	.504 (.010)	.043	.454 (.005)	.024	11.01
62	Augusta, Va.	20	9.2	65	.487 (.011)	.048	.448 (.008)	.036	8.71
63	Pendleton, W. Va.	20	7.7	66	.455 (.009)	.039	.436 (.008)	.034	4.36
64	Rockingham, Va.	20	9.6	74	.486 (.009)	.038	.446 (.007)	.032	8.97
65	Pendleton, W. Va.	20	8.3	55	.453 (.007)	.032	.415 (.006)	.028	9.16
66	Pendleton, W. Va.	20	8.9	87	.470 (.008)	.036	.440 (.006)	.027	6.82
67	Pocahontas, W. Va.	20	11.1	83	.490 (.008)	.034	.460 (.007)	.030	6.52

Table 1.—*Specific gravity of unextracted and extracted increment cores from pitch pine (continued)*

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
68	Pocahontas, W. Va.	20	8.4	56	.448 (.006)	.027	.426 (.007)	.030	5.16
69	Tucker, W. Va.	20	8.9	31	.438 (.004)	.018	.415 (.004)	.019	5.54
70	Tucker, W. Va.	20	8.1	35	.451 (.008)	.034	.431 (.005)	.022	4.64
71	Pocahontas, W. Va.	20	10.0	78	.502 (.012)	.054	.450 (.007)	.030	11.56
72	Pocahontas, W. Va.	20	10.6	80	.483 (.006)	.026	.451 (.006)	.028	7.10
73	Greenbrier, W. Va.	20	9.5	59	.501 (.006)	.025	.469 (.006)	.029	6.82
74	Monroe, W. Va.	20	11.0	49	.465 (.005)	.024	.431 (.006)	.029	7.89
75	Fayette, W. Va.	20	9.9	37	.446 (.005)	.022	.416 (.004)	.019	7.21
76	Kanawha, W. Va.	20	7.3	43	.475 (.011)	.048	.457 (.010)	.045	3.94
77	Washington, Ohio	20	8.2	36	.451 (.005)	.024	.413 (.004)	.020	9.20
78	Perry, Ohio	20	6.2	24	.446 (.006)	.029	.417 (.006)	.027	6.95
79	Lawrence, Ohio	20	9.0	44	.481 (.010)	.044	.438 (.007)	.032	9.82
80	Braxton, W. Va.	20	9.7	70	.487 (.007)	.031	.452 (.006)	.027	7.74
81	Somerset, Pa.	20	6.3	38	.445 (.009)	.040	.405 (.006)	.026	9.88
82	Fayette, Pa.	20	9.5	75	.496 (.010)	.043	.455 (.007)	.031	9.01
83	Boone, W. Va.	20	8.7	31	.446 (.009)	.042	.413 (.009)	.038	7.99
84	Boone, W. Va.	20	10.2	21	.405 (.005)	.021	.387 (.004)	.017	4.65
85	Greenup, Ky.	20	8.8	29	.434 (.005)	.024	.401 (.004)	.016	8.23
86	Rowan, Ky.	20	11.0	38	.489 (.014)	.061	.429 (.006)	.026	13.99
87	Wolfe, Ky.	20	8.5	34	.463 (.009)	.041	.426 (.005)	.021	8.69
88	Powell, Ky.	20	7.6	28	.455 (.008)	.037	.418 (.006)	.027	8.85
89	Jackson, Ky.	20	7.3	31	.485 (.008)	.034	.446 (.007)	.031	8.74
90	Green, Tenn.	20	8.7	38	.519 (.007)	.032	.477 (.007)	.032	8.81
91	Sullivan, Tenn.	20	11.1	70	.513 (.009)	.039	.477 (.007)	.032	7.55
92	Stokes, N. C.	20	13.3	97	.513 (.011)	.051	.454 (.005)	.021	13.00
93	Wilkes, N. C.	20	7.8	22	.435 (.007)	.030	.405 (.006)	.028	7.41
94	Caldwell, N. C.	20	10.7	53	.489 (.008)	.036	.458 (.007)	.030	6.77
95	Caldwell, N. C.	20	10.3	77	.521 (.013)	.057	.470 (.008)	.037	10.85
96	Madison, N. C.	20	8.6	45	.512 (.008)	.035	.463 (.005)	.023	10.58
97	Macon, N. C.	20	10.0	34	.430 (.008)	.037	.403 (.008)	.038	6.70
98	Graham, N. C.	20	10.0	33	.451 (.005)	.024	.425 (.005)	.024	6.12
99	Cherokee, N. C.	20	8.0	46	.526 (.008)	.037	.478 (.006)	.026	10.04
100	Cherokee, N. C.	20	8.2	29	.468 (.007)	.032	.439 (.007)	.032	6.61
	Total	2,000	9.9	59	.474 (.001)	.047	.435 (.001)	.035	8.97

d.b.h., age, and percentage difference resulting from extraction for each plot. The specific gravity of unextracted cores was 9 percent higher than extracted core specific gravity. This is considerably higher than the 6 to 7.5 percent difference reported for the four major species of southern yellow pine, spruce pine, and Table-Mountain pine (Taras and Saucier 1967, 1968; Clark and Saucier 1969) but is less than 9.7 percent difference reported for Choctawhatchee sand pine (Clark and Taras 1969). The average increment core specific gravity of pitch pine trees in the 5.0 to 8.9 inch diameter class decreased 7.8 percent when extractives were removed; trees in the 9.0 to 14.9 inch class decreased 9.6 percent, and those in the 15.0+ inch class decreased 10.5 percent.

The estimated tree specific gravities for pitch pine were obtained by using the following regression equation:

$$\text{Tree specific gravity } (Y) = 0.19438 + 0.54067(\text{sp. gr., 2 extracted cores}) + 2.01173(1/\text{age}) \quad (1)$$

When the specific gravity of 2,000 trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the average tree specific gravity was .471, with a standard error of .002.

The specific gravity of unextracted increment cores and the estimated tree specific gravity by three diameter classes (5.0 to 8.9 inches; 9.0 to 14.9 inches; and 15.0+ inches) are presented in table 2 for each Forest Survey Unit sampled in this survey.

Analyses of variance for unextracted and extracted increment core specific gravity and tests of significance for locations and trees within a location are presented in table 3. The unextracted and extracted increment core specific gravity of pitch pine

Table 2.—*Specific gravity for pitch pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity: Mean and standard error	Unextracted increment core specific gravity: Standard deviation	Estimated tree specific gravity[1] mean and standard error
	Number	*Inches*	*Number*			
Connecticut						
	2	5.0-8.9	16	.437 (.020)	.037	.470 (.010)
		9.0-14.9	24	.428 (.026)	.031	.457 (.008)
		15.0+	0	----	----	----
Kentucky						
Northern Cumberland (1)	4	5.0-8.9	47	.451 (.009)	.032	.498 (.011)
		9.0-14.9	30	.474 (.013)	.061	.477 (.008)
		15.0+	3	.463 (.017)	.032	.448 (.019)
Southern Cumberland (4)	1	5.0-8.9	17	.480 (.008)	.033	.504 (.012)
		9.0-14.9	3	.513 (.024)	.042	.506 (.020)
		15.0+	0	----	----	----
State total	5	5.0-8.9	64	.459 (.006)	.033	.499 (.010)
		9.0-14.9	33	.478 (.011)	.061	.480 (.008)
		15.0+	3	.463 (.018)	.032	.448 (.019)
Maine						
	2	5.0-8.9	18	.418 (.021)	.039	.455 (.009)
		9.0-14.9	17	.443 (.018)	.032	.457 (.009)
		15.0+	5	.442 (.016)	.035	.443 (.015)
Massachusetts						
	1	5.0-8.9	11	.428 (.009)	.031	.477 (.012)
		9.0-14.9	9	.433 (.008)	.023	.474 (.013)
		15.0+	0	----	----	----
New Hampshire						
	5	5.0-8.9	30	.453 (.019)	.063	.464 (.007)
		9.0-14.9	56	.444 (.012)	.047	.444 (.005)
		15.0+	14	.463 (.011)	.033	.439 (.009)
New Jersey						
	3	5.0-8.9	25	.455 (.002)	.026	.469 (.007)
		9.0-14.9	34	.474 (.004)	.035	.460 (.006)
		15.0+	1	.478 (----)	----	.458 (----)
New York						
East Adirondack (4)	1	5.0-8.9	10	.424 (.007)	.022	.466 (.012)
		9.0-14.9	10	.437 (.017)	.053	.451 (.011)
		15.0+	0	----	----	----
Capital District (7)	3	5.0-8.9	24	.445 (.009)	.038	.468 (.008)
		9.0-14.9	36	.439 (.004)	.039	.455 (.007)
		15.0+	0	----	----	----
State total	4	5.0-8.9	34	.439 (.007)	.036	.467 (.008)
		9.0-14.9	46	.439 (.003)	.049	.454 (.006)
		15.0+	0	----	----	----
North Carolina						
Piedmont (3)	1	5.0-8.9	1	.480 (----)	----	.468 (----)
		9.0-14.9	14	.515 (.015)	.056	.461 (.009)
		15.0+	5	.515 (.012)	.027	.458 (.015)
Mountain (4)	8	5.0-8.9	78	.476 (.015)	.052	.499 (.009)
		9.0-14.9	75	.482 (.013)	.064	.484 (.005)
		15.0+	7	.477 (.037)	.066	.475 (.013)
State total	8	5.0-8.9	79	.476 (.015)	.052	.498 (.008)
		9.0-14.9	89	.487 (.011)	.064	.480 (.004)
		15.0+	12	.493 (.021)	.057	.468 (.010)
Ohio						
South-central (1)	1	5.0-8.9	11	.471 (.014)	.046	.482 (.011)
		9.0-14.9	9	.494 (.010)	.031	.473 (.011)
		15.0+	0	----	----	----
Southeastern (2)	2	5.0-8.9	31	.447 (.001)	.026	.501 (.012)
		9.0-14.9	9	.455 (.009)	.027	.462 (.012)
		15.0+	0	----	----	----
State total	3	5.0-8.9	42	.453 (.005)	.034	.496 (.010)
		9.0-14.9	18	.474 (.014)	.036	.467 (.008)
		15.0+	0	----	----	----

Table 2.—*Specific gravity for pitch pine by states and by Forest Survey Units within states (continued)*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity: Mean and standard error	Unextracted increment core specific gravity: Standard deviation	Estimated tree specific gravity[1] mean and standard error
	Number	*Inches*	*Number*			
Pennsylvania						
Alleghany N.F. (1)	2	5.0-8.9	7	.473 (.024)	.027	.470 (.013)
		9.0-14.9	32	.478 (.005)	.053	.460 (.006)
		15.0+	1	.400 (----)	----	.425 (----)
Southwestern (4)	4	5.0-8.9	42	.477 (.020)	.051	.478 (.006)
		9.0-14.9	36	.493 (.002)	.036	.457 (.006)
		15.0+	2	.479 (.027)	.039	.444 (.024)
North-central (5)	9	5.0-8.9	40	.470 (.017)	.038	.474 (.006)
		9.0-14.9	126	.480 (.006)	.053	.462 (.003)
		15.0+	14	.480 (.003)	.035	.458 (.009)
South-central (6)	8	5.0-8.9	33	.472 (.013)	.042	.473 (.006)
		9.0-14.9	97	.492 (.006)	.049	.463 (.004)
		15.0+	30	.499 (.012)	.048	.455 (.007)
Northeastern (7)	8	5.0-8.9	70	.477 (.005)	.043	.469 (.004)
		9.0-14.9	73	.475 (.006)	.046	.453 (.004)
		15.0+	17	.457 (.011)	.034	.445 (.008)
Southeastern (8)	2	5.0-8.9	22	.506 (.004)	.038	.486 (.008)
		9.0-14.9	16	.513 (.002)	.036	.467 (.009)
		15.0+	2	.469 (.004)	.008	.453 (.024)
State total	33	5.0-8.9	214	.478 (.003)	.037	.474 (.003)
		9.0-14.9	380	.484 (.001)	.045	.460 (.002)
		15.0+	66	.481 (.001)	.044	.452 (.005)
Tennessee						
Eastern (5)	2	5.0-8.9	16	.510 (.025)	.041	.510 (.011)
		9.0-14.9	23	.519 (.008)	.031	.488 (.008)
		15.0+	1	.556 (----)	----	.473 (----)
Virginia						
Northern Mountain (4)	11	5.0-8.9	110	.492 (.008)	.041	.485 (.004)
		9.0-14.9	98	.503 (.007)	.053	.470 (.004)
		15.0+	12	.512 (.010)	.047	.468 (.010)
Southern Mountain (5)	1	5.0-8.9	7	.506 (.017)	.044	.480 (.013)
		9.0-14.9	13	.483 (.008)	.030	.462 (.009)
		15.0+	0	----	----	----
State total	12	5.0-8.9	117	.493 (.007)	.041	.485 (.004)
		9.0-14.9	111	.500 (.008)	.045	.469 (.003)
		15.0+	12	.512 (.014)	.047	.468 (.010)
West Virginia						
Northeastern (2)	13	5.0-8.9	122	.463 (.005)	.034	.477 (.005)
		9.0-14.9	132	.477 (.007)	.049	.465 (.003)
		15.0+	6	.481 (.018)	.057	.459 (.014)
Southern (3)	6	5.0-8.9	54	.453 (.014)	.040	.496 (.009)
		9.0-14.9	62	.461 (.013)	.038	.480 (.006)
		15.0+	4	.426 (.012)	.032	.459 (.017)
State total	19	5.0-8.9	176	.460 (.004)	.036	.483 (.005)
		9.0-14.9	194	.472 (.004)	.046	.470 (.003)
		15.0+	10	.459 (.009)	.053	.459 (.010)
All States	100	5.0-8.9	842	.468 (.001)	.043	.482 (.005)
		9.0-14.9	1034	.477 (.001)	.045	.465 (.001)
		15.0+	124	.480 (.002)	.044	.454 (.003)
Total all classes	100		2,000	.474 (.001)	.047	.471 (.002)

[1]Estimates were made with equation (1):

$$Y = 0.19438 + 0.54067 \text{ (sp. gr., 2 extracted cores)} + 2.01173 \text{ (1/age)}.$$

Table 3.—*Analyses of variance for pitch pine specific gravity and, tests of significance for locations and trees within a location*

Source	d.f.	Unextracted		Extracted	
		MS	F ratio	MS	F ratio
Among locations	99	0.0326	12.07**	0.0250	14.71**
Among trees within locations	1,900	0.0027	3.37**	0.0017	4.25**
Among cores within trees	2,000	0.0008		0.0004	
Total	3,999				

**Significant at the .01 probability level.

varied more between plots than among trees within a plot, as was found for spruce pine and Table-Mountain pine (Taras and Saucier 1968; Clark and Saucier 1969).

The data in table 1 are also shown in figure 1 to illustrate specific gravity changes with geographic location. Correlation analyses indicated that unextracted and extracted increment core specific gravities were significantly associated with latitude and longitude. But examination of the data in figure 1 suggested that the differences in specific gravity were not continuous in a north-south or east-west trend, but rather varied between two discrete regional areas—the northeast (New England and New York) and the remainder of the range.

To examine regional changes in specific gravity, the range of pitch pine was divided into four regions: (1) Northeast (New England and New York); (2) North Central (Pennsylvania and New Jersey); (3) Central (Virginia, West Virginia, Maryland, Ohio, and Kentucky); (4) Southern (North Carolina, South Carolina, Tennessee, and Georgia).

With an analysis of covariance to adjust for the effects of age and d.b.h., unextracted and extracted increment core specific gravities were found to vary significantly among geographic regions (tables 5 and 6, Appendix). The adjusted mean unextracted specific gravity of the Northeast region (table 4) is considerably lower than the adjusted mean unextracted specific gravities of the other three regions. The average observed unextracted increment core specific gravity of the Northeast was .440 and the Southern region averaged .409, a difference of 11.1 percent based on the Northeast value. After extraction, the mean extracted increment core specific gravity of the Northeast region was still significantly lower than all other regions; the average in the Northeast region was 8.8 percent less than the average of trees sampled in the other geographic regions.

These results indicate that two races or ecotypes of pitch pine might exist. One race occurs on sandy, outwash plains of glacial origin along the coast and in river valleys in New England and New York, and the other is found on shallow soils on steep slopes, ridges, and plateaus throughout the Appalachian Mountains.

Table 4.—*Mean d.b.h., age, and increment core specific gravity for geographic regions. (Increment core specific gravity values were adjusted by covariance analyses for the effects of age and d.b.h.)*

Geographic regions	Trees sampled	Mean d.b.h.	Mean age	Mean increment core specific gravity			
				Unextracted		Extracted	
				Unadjusted	Adjusted	Unadjusted	Adjusted
	Number	*Inches*	*Years*				
Northeast	280	10.2	48	.440	.448	.395	.407
North Central	720	10.5	74	.480	.471	.440	.433
Central	780	9.2	52	.475	.479	.439	.441
Southern	220	9.7	49	.489	.495	.450	.455
Species average		9.9	59	.474	.474	.439	.435

Increment Core / Tree Specific Gravity Relationships—Simple Linear and Multiple Regression Analyses

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request and will not be treated in detail here. All regression equations developed from these data for predicting tree specific gravity of pitch pine are presented in table 7 in the Appendix. Table 8 in the Appendix contains the means and standard deviations of all the independent variables used to analyze increment core/tree specific gravity relationships.

From these data, the best equation developed for predicting tree specific gravity of pitch pine was:

$$Y = 0.22565 + 0.53777(\text{sp. gr., outer } 2/3 \text{ of } 2 \text{ extracted cores}) + 0.55637(1/\text{age}) - 0.00149(\text{d.b.h.}) \quad (2)$$

This equation had a correlation coefficient of .78 and was associated with 61 percent of the variation about regression. The standard error about regression for equation (2) was .017.

Equation (1) was used in this study to adjust increment core specific gravity of pitch pine to tree specific gravity. This equation was used instead of the best one developed because the specific gravity was determined for only whole cores in the large sample. Equation (1) had a correlation coefficient of .71 and was associated with 50 percent of the variation about regression.

Relationship of Unextracted and Extracted Specific Gravity

The specific gravity of all increment cores was determined in both the unextracted and extracted condition. From these data, a regression equation for predicting extracted specific gravity from unextracted specific gravity was developed. Equation (3) has a correlation coefficient of .82 and a standard error about regression of .021:

$$Y = 0.11241 + 0.68125\ X_1 \quad (3)$$

Where: Y = specific gravity of 2 extracted increment cores
X_1 = specific gravity of 2 unextracted increment cores

Similar high correlations have been reported for the relationship between unextracted and extracted increment core specific gravity for other minor species of southern yellow pine (Taras and Saucier 1968; Clark and Taras 1969; Clark and Saucier 1969).

SUMMARY AND CONCLUSIONS

The average specific gravity of pitch pine was .474. The same increment cores had an average specific gravity of .435, a decrease of 9 percent, after extraction. An equation is presented for predicting extracted increment core specific gravity from unextracted increment core specific gravity.

Unextracted and extracted increment core specific gravities of pitch pine were significantly correlated with latitude and longitude. The average unextracted increment core specific gravity of pitch pine in New England and New York was 11.1 percent less than the average increment core specific gravity of pitch pine in North Carolina, South Carolina, and Tennessee. After the extractives were removed, the extracted increment core specific gravity of the Northeast region was still significantly lower than all other regions. These regional differences in increment core specific gravity indicated the possible existence of two races or ecotypes of pitch pine. One race occurs on sandy, outwashed plains in New England and New York, while the other occurs on shallow soil on the ridges and plateaus of the Appalachian Mountains.

The best equation developed for predicting pitch pine tree specific gravity involved three independent variables: (1) specific gravity of the outer 2/3 of 2 extracted cores, (2) 1/age, and (3) d.b.h. These variables explained 61 percent of the variation in tree specific gravity. Since the increment cores taken in the survey were not segmented when their specific gravity was determined, equation (1) was used to adjust pitch pine increment core specific gravity to tree specific gravity. The variables in the equation accounted for 50 percent of the variation about regression.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2}\right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity (Y) $= b_0 + b_1 X_1 + b_2 X_2$

   where: Y = tree specific gravity
   X_1 = average specific gravity of 2 extracted cores
   X_2 = 1/age

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} = \left[S^2_{y.x}\left(\frac{1}{m_2 n_2} + C_{11}(\bar{x}_{1,1} - \bar{x}_{1,2})^2 + C_{22}(\bar{x}_{2,1} - \bar{x}_{2,2})^2 + 2C_{12}(\bar{x}_{1,1} - \bar{x}_{1,2})(\bar{x}_{2,1} - \bar{x}_{2,2})\right) + \frac{S^2_y}{m_1 n_1}\right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares
   S^2_y = variance of y prior to adjustment for regression
   $\bar{x}_{1,1}$ = mean core specific gravity of trees from which only cores were collected, sample (1)
   $\bar{x}_{1,2}$ = mean core specific gravity of trees collected for tree-core relationships, sample (2)
   $\bar{x}_{2,1}$ = mean d.b.h./age for sample (1)
   $\bar{x}_{2,2}$ = mean d.b.h./age for sample (2)
   m_1 = number of trees at each location, sample (1)
   m_2 = number of trees at each location, sample (2)
   n_1 = number of locations, sample (1)
   n_2 = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \dfrac{\text{unextracted core sp. gr.} - \text{extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Table 5.—*Analysis of covariance for pitch pine unextracted increment core specific gravity, adjusted for age and d.b.h., and test of significance for geographic regions*

Source	d.f.	Y Y	Sums-squares (due to regression)	Sums-squares (about regression)	d.f.	Mean squares
Among regions	3	0.4052				
Within regions	1,996	3.7444	0.4422	3.3022	1,994	0.0017
Treatments + error	1,999	4.1496	0.5392	3.6104	1,997	
Region means adjusted for age and d.b.h.				0.3082	3	0.1027**

**Significant at the .01 probability level.

Table 6.—*Analysis of covariance for pitch pine extracted increment core specific gravity, adjusted for age and d.b.h., and test of significance for geographic regions*

Source	d.f.	Y Y	Sums-squares (due to regression)	Sums-squares (about regression)	d.f.	Mean squares
Among regions	3	0.4365				
Within regions	1,996	2.3888	0.2795	2.1093	1,994	0.0011
Treatments + error	1,999	2.8253	0.3714	2.4539	1,997	
Region means adjusted for age and d.b.h.				0.3446	3	0.1149**

**Significant at the .01 probability level.

Table 7.—*Regression equations, correlation coefficients, coefficients of determination, and standard errors about regressions for pitch pine increment core/tree specific gravity relationships*

Regression equations	r	r^2	Standard error
Tree specific gravity (Y):			
Y = 0.22565 + 0.53777 (sp. gr., outer 2/3 of 2 extracted cores) + 0.55437 (1/age) — 0.00149 (d.b.h.)	0.78	0.61	0.017
Y = 0.23549 + 0.56677 (weighted sp. gr., 2 extracted cores) — 0.00021 (total height) — 0.00167 (d.b.h.)	0.77	0.59	0.018
Y = 0.23491 + 0.54764 (sp. gr., outer 2/3 of 2 extracted cores) — 0.00198 (d.b.h.)	0.77	0.59	0.017
Y = 0.24480 + 0.53068 (weighted sp. gr., 2 extracted cores) — 0.00205 (d.b.h.)	0.76	0.58	0.018
Y = 0.28272 + 0.42604 (weighted sp. gr., 1 extracted core) + 0.54520 (1/age) — 0.00198 (d.b.h.)	0.74	0.55	0.019
Y = 0.29493 + 0.44659 (sp. gr., outer 1/3 of 2 extracted cores) — 0.03044 (d.b.h./age) — 0.00068 (total height)	0.74	0.55	0.019
Y = 0.20764 + 0.56885 (weighted sp. gr., 2 extracted cores)	0.74	0.55	0.018
Y = 0.19824 + 0.58592 (sp. gr., outer 2/3 of 2 extracted cores)	0.74	0.55	0.018
Y = 0.29205 + 0.44861 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00073 (total height)	0.74	0.55	0.018
Y = 0.27653 + 0.42636 (sp. gr., outer 2/3 of 1 extracted core) + 0.72749 (1/age) — 0.00180 (d.b.h.)	0.74	0.55	0.018
Y = 0.29224 + 0.43504 (weighted sp. gr., 1 extracted core) — 0.00247 (d.b.h.)	0.73	0.53	0.019
Y = 0.29038 + 0.43585 (sp. gr., outer 2/3 of 1 extracted core) — 0.00246 (d.b.h.)	0.73	0.53	0.019
Y = 0.25654 + 0.46706 (sp. gr., 1 extracted core) + 1.37330 (1/age) — 0.00190 (d.b.h.)	0.72	0.52	0.019
Y = 0.22646 + 0.52940 (sp. gr., 2 extracted cores) + 1.39142 (1/age) — 0.00176 (d.b.h.)	0.72	0.52	0.019
Y = 0.22343 + 0.47546 (sp. gr., 1 extracted core) + 2.04752 (1/age)	0.71	0.50	0.019
Y = 0.19438 + 0.54067 (sp. gr., 2 extracted cores) + 2.01173 (1/age)	0.71	0.50	0.019
Y = 0.25347 + 0.46750 (weighted sp. gr., 1 extracted core)	0.69	0.48	0.020
Y = 0.34288 + 0.32967 (sp. gr., outer 1/3 of 1 extracted core) — 0.00037 (total height) — 0.00147 (d.b.h.)	0.69	0.48	0.020
Y = 0.25160 + 0.46846 (sp. gr., outer 2/3 of 1 extracted core)	0.69	0.48	0.020
Y = 0.29715 + 0.35858 (sp. gr., outer 1/3 of 2 extracted cores)	0.69	0.48	0.020
Y = 0.35402 + 0.28121 (sp. gr., outer 1/3 of 1 extracted core) — 0.00220 (d.b.h.)	0.68	0.46	0.020
Y = 0.33574 + 0.29749 (sp. gr., outer 1/3 of 2 cores) — 0.00180 (d.b.h.)	0.68	0.46	0.020
Y = 0.32199 + 0.31518 (sp. gr., outer 1/3 of 2 cores) + 0.00016 (age) — 0.00235 (d.b.h.)	0.68	0.46	0.020
Y = 0.34723 + 0.33793 (weighted sp. gr., 2 cores) + 0.00138 (merch. vol.) — 0.00621 (d.b.h.)	0.67	0.45	0.020
Y = 0.30443 + 0.32583 (sp. gr., outer 1/3 of 2 cores)	0.66	0.44	0.020
Y = 0.33987 + 0.28671 (weighted sp. gr., 1 core) + 0.01294 (total height/age) — 0.00253 (d.b.h.)	0.65	0.42	0.021
Y = 0.31360 + 0.36538 (weighted sp. gr., 2 cores) — 0.00265 (d.b.h.)	0.65	0.42	0.021
Y = 0.32003 + 0.30820 (sp. gr., outer 1/3 of 1 extracted core)	0.65	0.42	0.021
Y = 0.36071 + 0.32309 (sp. gr., outer 2/3 of 2 cores) + 0.00184 (merch. vol.) — 0.00735 (d.b.h.)	0.65	0.42	0.021
Y = 0.36498 + 0.24571 (sp. gr., outer 1/3 of 1 core) — 0.00225 (d.b.h.)	0.64	0.41	0.021
Y = 0.35721 + 0.25529 (sp. gr., outer 1/3 of 1 core) + 0.00010 (age) — 0.00261 (d.b.h.)	0.64	0.41	0.021
Y = 0.24932 + 0.49097 (sp. gr., 1 extracted core)	0.63	0.40	0.021
Y = 0.21774 + 0.56059 (sp. gr., 2 extracted cores)	0.63	0.40	0.021
Y = 0.33857 + 0.31712 (weighted sp. gr., 1 core) — 0.00281 (d.b.h.)	0.63	0.40	0.021
Y = 0.34767 + 0.26054 (sp. gr., outer 2/3 of 1 core) + 0.01717 (total height/age) — 0.00241 (d.b.h.)	0.63	0.40	0.021
Y = 0.32211 + 0.34741 (sp. gr., outer 2/3 of 2 cores) — 0.00266 (d.b.h.)	0.62	0.38	0.021
Y = 0.32975 + 0.27297 (sp. gr., outer 1/3 of 1 core)	0.61	0.37	0.022
Y = 0.27065 + 0.40080 (weighted sp. gr., 2 cores)	0.60	0.36	0.022
Y = 0.37028 + 0.22436 (sp. gr., 1 core) + 0.01988 (total height/age) — 0.00306 (d.b.h.)	0.60	0.36	0.022
Y = 0.36517 + 0.23046 (sp. gr., 2 cores) + 0.02142 (total height/age) — 0.00303 (d.b.h.)	0.60	0.36	0.022
Y = 0.35108 + 0.29046 (sp. gr., outer 2/3 of 1 core) — 0.00282 (d.b.h.)	0.59	0.35	0.022
Y = 0.29629 + 0.34787 (weighted sp. gr., 1 core)	0.57	0.32	0.022
Y = 0.38004 + 0.24907 (sp. gr., 1 core) — 0.00363 (d.b.h.)	0.56	0.31	0.023
Y = 0.27765 + 0.38591 (sp. gr., outer 2/3 of 2 cores)	0.56	0.31	0.022
Y = 0.37842 + 0.25119 (sp. gr., 2 cores) — 0.00364 (d.b.h.)	0.55	0.30	0.023
Y = 0.30745 + 0.32388 (sp. gr., outer 2/3 of 1 core)	0.53	0.28	0.023
Y = 0.34114 + 0.25575 (sp. gr., 1 core)	0.43	0.18	0.024
Y = 0.33950 + 0.25749 (sp. gr., 2 cores)	0.42	0.18	0.025

Table 8.—*Mean and standard deviation of the dependent and independent variables used to develop regression equations for the increment core/tree specific gravity relationships for pitch pine*

Variables	Mean	Standard deviation
Dependent		
Weighted tree specific gravity	0.461	0.027
Independent		
D.b.h.	9.869	2.657
Total height	49.150	11.494
Age	67.540	18.163
Merchantable volume	10.472	7.309
D.b.h./age	0.150	0.036
1/age	0.016	0.004
Merchantable volume/age	0.153	0.101
Total height/age	0.790	0.323
Specific gravity, 1 core	0.467	0.045
Specific gravity, outer 2/3 of 1 core	0.473	0.044
Specific gravity, outer 1/3 of 1 core	0.479	0.060
Specific gravity, 2 cores	0.470	0.044
Specific gravity, outer 2/3 of 2 cores	0.474	0.039
Specific gravity, outer 1/3 of 2 cores	0.479	0.054
Weighted specific gravity, 1 core	0.472	0.044
Weighted specific gravity, 2 cores	0.474	0.040
Specific gravity, 1 extracted core	0.430	0.034
Specific gravity, outer 2/3 of 1 extracted core	0.446	0.040
Specific gravity, outer 1/3 of 1 extracted core	0.456	0.057
Specific gravity, 2 extracted cores	0.433	0.030
Specific gravity, outer 2/3 of 2 extracted cores	0.448	0.034
Specific gravity, outer 1/3 of 2 extracted cores	0.456	0.052
Weighted specific gravity, 1 extracted core	0.443	0.040
Weighted specific gravity, 2 extracted cores	0.445	0.035

Saucier, Joseph R., and Clark, Alexander III
1970. Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States. Part IV--Pitch Pine (Pinus rigida Mill.). Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-63, 16 pp.

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