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Pin Oak Acorn Production and Regeneration as Affected by Stand Density, Structure and Flooding

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LEON S. MINCKLER AND ROBERT E. McDERMOTT*

Pin oak *(Quercus palustris* Muench.) is an important tree species common on wet, heavy soils in the Central States region. Until recently, however, the silvics of this species has been neglected (Minckler, 1957). In an effort to provide some of the missing information, a study was begun several years ago to find out more about pin oak acorn production and regeneration. The work gained impetus because of the increasing practice of artificially flooding pin oak flats during the winter to create fall and winter wild duck habitat through the establishment of "green tree reservoirs." Resource managers and landowners wanted to know what effect such flooding would have on acorn production, on regeneration, and on the trees themselves. So four of the public agencies concerned** set up a study to get basic information on pin oak acorn production and regeneration as related to stand density and structure, and also to find out how flooding would affect these phenomena. Results for the acorn production and regeneration phases of this study are reported here.

DESCRIPTION OF EXPERIMENTAL SITES

The study was conducted on two areas in the Mingo swamp region of southeastern Missouri, near Puxico. The sites are typically flat, poorly drained and with heavy clay soil. The Mingo area of about 30,000 acres lies in an old valley abandoned by the Mississippi River during the Quarternary period. Until that time, the Mississippi River flowed near the present site of Poplar Bluff, Missouri. Subsequently, the St. Francis River formed a delta across the old Mingo channel, thus providing an effective drainage barrier. Some water was carried away by the Old Mingo River, the original drainage of the swamp, but for the most part runoff from the surrounding hills kept the basin filled. Sediment was

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**The study was made cooperatively by the University of Missouri, the Central States Forest Experiment Station, the U. S. Fish and Wildlife Service (Lyle Schoonover), and the Missouri Conservation Commission (George K. Brakhage) on federal and state owned lands in the Mingo area of southeastern Missouri. Wildlife aspects of this study will be reported separately in a subsequent publication.

continuously washed into the basin, thus depositing a thick layer of alluvial soil above the old river sand. Much of the area is now public land administered by the U. S. Fish and Wildlife Service and by the Missouri Conservation Commission.

In this Mingo area the original forest was composed chiefly of cypress (*Taxodium distichum* (L.) Rich.), various wetland oaks, and gums. Heavy cutting and repeated fires changed the composition to pure pin oak, pin oak mixed with oaks and gum, or non-timber brushy species.

On one of the areas studied, flooding occurs normally, i.e., 1 to 4 times per year for 2 to 10 days each time. This area is administered by the U. S. Fish and Wildlife Service and covers many thousands of acres. Study plots were scattered over an area of approximately 200 acres.

The other area, operated by the Missouri Conservation Commission, consists of a 600-acre area surrounded with low levees. Each year in mid-November it is artificially flooded with water 1 to 3 feet deep to serve as a public duck-shotting area. Water is supplied from an 1,800-acre permanent reservoir fed by the Castor River. About mid-February the flooded area is drained through a man-made ditch.

In this bulletin the U. S. Fish and Wildlife land is referred to as the "normal" area and the Missouri Conservation land as the "flooded" area.

DESCRIPTION OF STANDS

The present studies† were established in mostly pure, even-aged pin oak stands 25 to 35 years old with a few trees as old as 40 years. In 1956 the dominant and codominant trees in the pin oak stands were 62 to 67 feet tall on both the flooded and normal areas. The site index for these stands at age 50 years was estimated to range between 75 and 85 feet.

Pin oak is the predominant species in the stands (table 1). Other species found less frequently include willow oak, *(Quercus phellos* L.) overcup oak *(Quercus lyrata* Walt.) and several less frequent tree species including ash *(Fraxinus)* and elm *(Ulmus).* Although pin oak was predominant in both areas, the normal area had more willow oak and miscellaneous species than the flooded area.

The diameter distribution of trees was about the same on the flooded and normal areas. The average basal area on all the plots was 82 square feet. These were generally well but not fully stocked stands.

METHODS OF STUDY

Treatments

In each area, 18 half-acre plots were laid out. Half of these plots were in stands where small trees predominated (two-thirds of the basal area in trees 10 inches d.b.h. or less) and half were in stands where larger trees predominated

†In addition to acorn production, silvicultural studies underway include pruning studies and studies of pin oak growth and quality as affected by stand density and tree diameter distribution.

TABLE 1-SPECIES COMPOSITION OF STANDS BEFORE TREATMENT, TREES 5 INCHES D.B.H. AND LARGER
(In number of trees per acre)

Species	Normal area	Flooded area
Pin oak	107	145
Overcup oak	22	36
Willow oak	32	1
Miscellaneous species	40	13
Total	201	195

(two-thirds of the basal area in trees more than 10 inches d.b.h.) (tables 2 and 3). In the small-tree stands, 3 plots selected at random were cut to 40 square feet basal area, 3 were cut to 60 square feet basal area, and the remaining 3 were left as checks with 75 to 90 square feet basal area. The 9 plots in the large-tree stands were similarly treated. In August 1957, when all areas were free of standing water, half of each plot was disked to see whether exposing mineral soil would stimulate acorn germination.

TABLE 2-DIAMETER DISTRIBUTION OF TREES IN STANDS BEFORE TREATMENT AND TREATMENT GOALS AFTER CUTTING
(In percent of total basal area)

Tree diameter class (Inches)	"Small-tree" structure			"Large-tree" structure		
	Normal area	Flooded area	Treatment goals	Normal area	Flooded area	Treatment goals
5-7	28	26	25	13	14	10
8-10	38	41	45	28	28	25
11-13	21	24	25	31	35	35
14-16	7	9	5	18	19	25
17+	6	0	0	10	4	5
Basal area per acre (square feet)	86	74	--	86	81	--

TABLE 3-NUMBER OF PIN OAK AND WILLOW OAK TREES 11 INCHES D.B.H. AND LARGER AFTER CUTTING
(Number per acre)

Treatments; stand density	Normal area		Flooded area	
	"Small-tree" structure	"Large-tree" structure	"Small-tree" structure	"Large-tree" structure
Low (40 square feet basal area)	13	25	15	27
Medium (60 square feet basal area)	11	32	23	38
High (75-90 square feet basal area)	26	33	21	47

Data Collection

Twenty-five bushel-basket seed traps were equally spaced in each of the 36 plots, a total of 900 seed traps (fig. 1) Traps were numbered and recorded by position in relation to the crown canopy as (1) under a crown, (2) edge of crown, and (3) in an opening. Traps were screened by fastening 1-inch-mesh wire screen about half-way down in the basket. This eliminated pilferage by birds and animals and prevented the acorns from bouncing out of the basket when they hit the screen, as sometimes happens when the screen is placed across the top of the basket.

Seedfall for 1956, 1957, and 1958, forms the main basis for the analysis presented here. In addition, 1959 data, although not yet completely analyzed, are included wherever possible. The condition of acorns was determined by cutting tests where required. All acorns‡ were grouped in 4 classes as follows:

(1) Well developed, sound, and undamaged;

(2) Well developed and sound, but damaged by animals or mechanical means;

Fig. 1.—Bushel-basket seed trap in place in a plot of the flooded area. The support stake is slanted to make the top of the basket level. Additional baskets can be seen in the background. This scene is typical on the flooded area from mid-November to mid-February.

‡Mostly pin oak but willow oak acorns are not separated in the data. The very few overcup oak acorns were not counted.

(3) Well developed, but insect infested;
(4) Underdeveloped or deformed, usually aborted.

Class 1 and many class 2 acorns would normally germinate and produce seedlings, if conditions were favorable. Class 3 and 4 acorns would be useless for production of seedlings.

In June and July 1959, 20 circular subplots, each 10 feet in diameter, were established in each plot (half in the disked portion and half in the undisked) to sample reproduction.

All reproduction up to 0.6 inches d.b.h. was tallied by height, species, and age class, and classified as: (1) present before time of scarification in August 1957; (2) spring, 1958 seedling; and (3) spring, 1959 seedlings. All other species of reproduction were further classed as advanced (present prior to 1958) or new.

RESULTS ON THE NORMAL AREA

Acorn Production

During the study period—1956 through 1959—there was one good seed crop, in 1957, when an average of 188,000 sound, well-developed acorns (classes 1 and 2) per acre were produced. Production, during each of the other three years, never exceeded 25,000 per acre and was as low as 2,200, in 1959 (table 4). Tree size seemed to be the major influence on seed production: large-tree stands consistently produced more acorns than small-tree stands (table 5 and figure 2). In 1957, the good seed year, moreover, size of the acorn crop was correlated with basal area as well as with tree size. The number of defective acorns (classes 3 and 4) had about the same relation to stand density and structure as the sound, well-developed, acorns (table 6). (See tables 10 and 11 in Appendix for basic data.)

Acorn Quality

Neither stand density nor tree size seemed to influence seed quality but size of seed crop did: the larger the crop the higher the percentage of sound acorns (fig. 3). In the poorest seed year, 1956, only about 12 percent of all acorns were

TABLE 4-AVERAGE PRODUCTION OF SOUND, WELL-DEVELOPED PIN OAK ACORNS BY YEARS

Year	Number of acorns per acre	
	Normal area	Flooded area
1956	8,000	400
1957	188,000	201,000
1958	24,000	96,000
1959	2,200	12,700

TABLE 5-NUMBER OF WELL-DEVELOPED, SOUND* ACORNS PER ACRE BY YEARS AND TREATMENTS
(In thousands of acorns)

Stocking structure treatment	Normal area			Flooded area		
	1956 crop	1957 crop	1958 crop	1956 crop	1957 crop	1958 crop
Low stocking						
Small trees	4	110	7	0.0	183	133
Large trees	15	182	29	0.3	147	89
Medium stocking						
Small trees	1	122	28	0.3	145	41
Large trees	14	226	30	0.8	283	71
Heavy stocking						
Small trees	4	169	30	0.3	216	105
Large trees	9	318	22	0.8	231	139

*Class 1 and 2 acorns. Does not include insect-damaged or under-developed acorns.

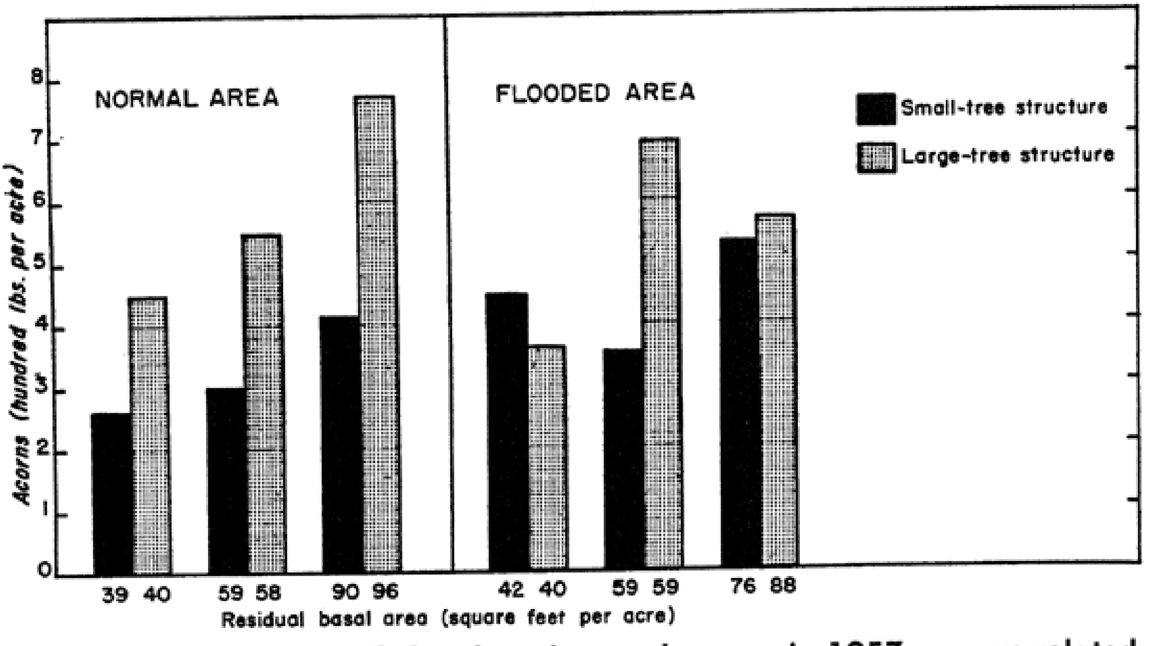

Fig. 2.—Quantity of well-developed, sound acorns in 1957 crop as related to stocking and structure of residual stand.

sound. In the best seed year, 1957, 68 percent of all acorns were sound. However, when the crop exceeded about 150,000 acorns per acre the proportion of sound acorns did not increase (see tables 12, 13, 14 in Appendix for basic data).

Distribution of Acorns on the Ground

The largest number of sound, undamaged acorns, both in 1957 and 1958, was found in traps under the canopy and the lowest number in openings in the

TABLE 6-TOTAL DEFECTIVE ACORNS* PER ACRE BY STOCKING-STRUCTURE AND YEARS
(In thousands of acorns)

Stocking and structure	1956 crop		1957 crop		1958 crop	
	Normal	Flooded	Normal	Flooded	Normal	Flooded
Low stocking						
Small trees	26	11	42	31	22	47
Large trees	67	14	72	38	51	52
Medium stocking						
Small trees	23	26	52	61	41	34
Large trees	98	19	129	57	69	39
High stocking						
Small trees	39	20	82	65	57	44
Large trees	71	27	209	82	56	40

*Class 3 and 4 acorns.

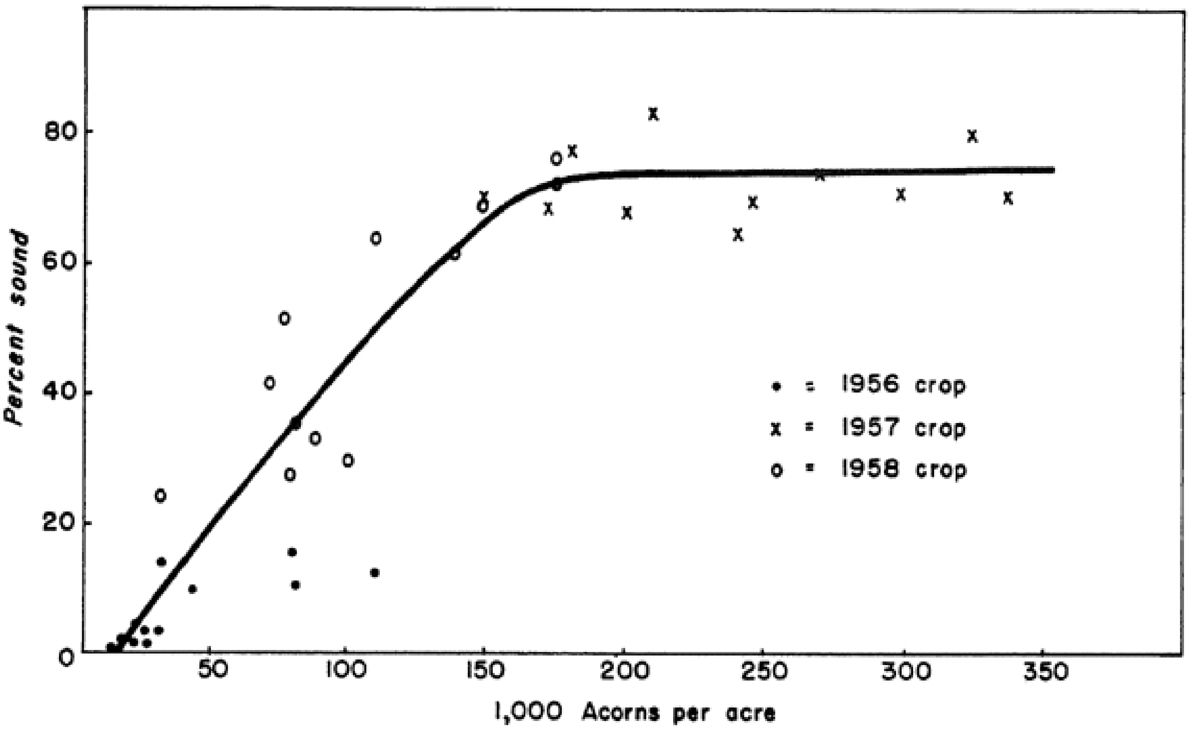

Fig. 3.—Relation between total amount of acorn crop and percent of acorns sound.

canopy (fig. 4 and tables 15 and 16). However, there were relatively more acorns in the openings in the small-tree than in the large-tree stands. This may have been caused by a greater "whipping" action of smaller trees in strong winds.

The number of sound acorns distributed over the entire plot areas, including openings and edges, was enough for adequate reproduction if other conditions were favorable. The distribution of well-developed but damaged acorns (class 2) over the plots was essentially the same as for the sound, undamaged acorns (tables 17 and 18).

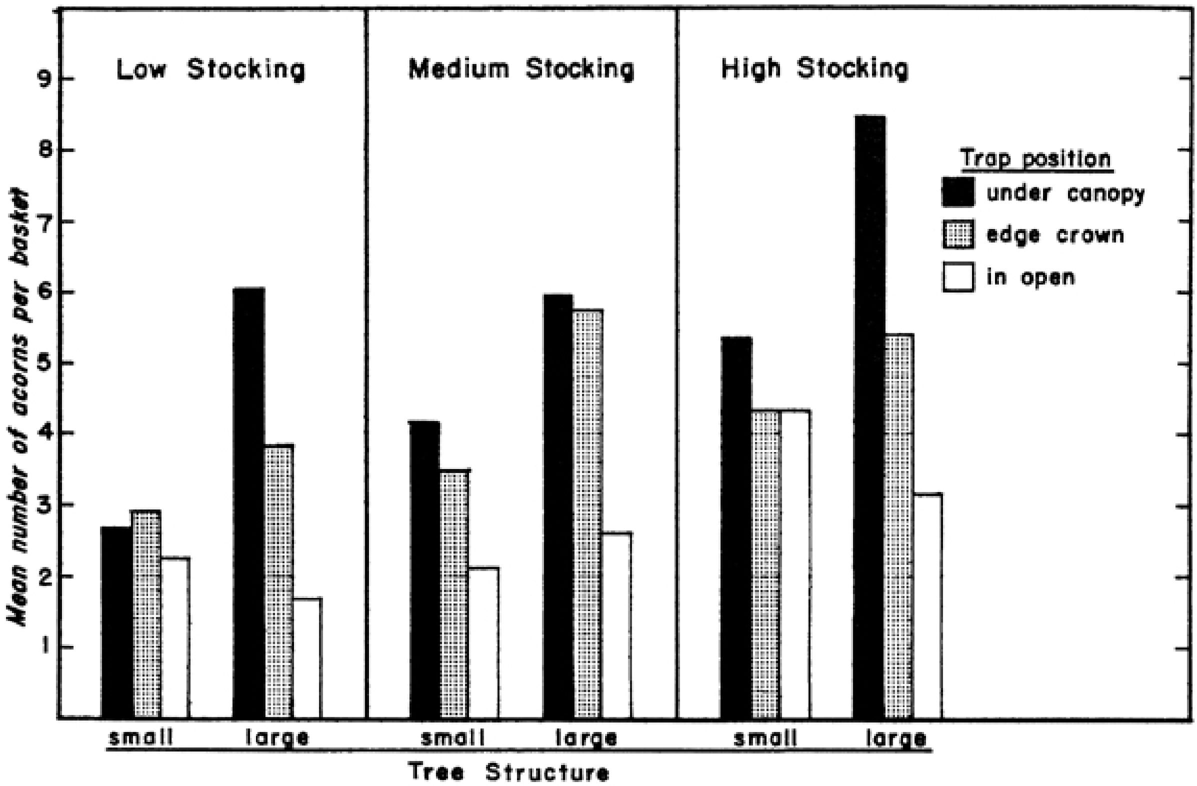

Fig. 4.—Number of well-developed, sound and undamaged acorns (class 1) per trap as related to position of the trap and the stocking-structure; 1957 crop on flooded area.

Oak Reproduction

The best year for reproduction establishment was 1958, following the good seed crop of 1957 (table 7). An average of 3,500 one year old oak seedlings per acre were present in June-July 1959—one for every 26 sound, undamaged acorns produced. Again, neither stand density nor structure seemed to exert a significant influence.

The ground scarification in August, 1957, apparently benefited the establishment of oak seedlings in the spring of 1958. Scarified portions of the plots had an average of 4400 seedlings per acre, in 1959, while unscarified portions had 2600. While scarification on the normal area increased oak seedling establishment, there were still sufficient seedlings on the unscarified portions to make a well-stocked stand. In upland stands, moderately thick litter has not been detrimental to oak regeneration and in some cases it has been beneficial (Minckler and Jensen, 1959). Typical pin oak areas usually flood sometime during the winter and it can be expected that acorns would be covered with some silt and leaves. With their relatively large amount of stored food and water, acorns do not, normally, require immediate access to mineral soil for moisture and nutrients when germination occurs. The results on the normal area, however, indicate that scarification before seed fall helps seedling establishment the following spring.

TABLE 7-NUMBER OF OAK SEEDLINGS PER ACRE IN JUNE-JULY 1959 BY TREATMENTS AND CONDITION OF FLOODING*

		1959 seedlings		1958 seedlings		Advanced seedlings**	
Structure	Stocking	Normal	Flooded	Normal	Flooded	Normal	Flooded
PIN OAK							
Large	Low	0	37	2,193	166	203	516
	Medium	9	101	1,592	28	28	544
	High	9	9	1,622	28	55	378
Small	Low	28	37	2,986	56	138	461
	Medium	0	46	5,068	28	28	507
	High	0	28	5,262	28	28	120
WILLOW OAK							
Large	Low	0	0	1,060	0	276	46
	Medium	0	0	729	0	102	157
	High	0	0	138	0	258	46
Small	Low	0	0	46	0	175	221
	Medium	9	0	138	0	83	65
	High	0	0	203	0	802	240
Mean all oak seedlings		9	43	3,506	56	363	550
Total sound, undamaged acorns		3,300	57,000	92,000	117,000	---	---
Number of acorns per seedling		367	1,325	26	2,089	---	---

* Each value within table based on 60 reproduction plots in 3 half-acre stocking-structure plots.

** Present before spring of 1958.

Advanced oak reproduction was moderately plentiful in the summer of 1959. Advanced pin oak reproduction was more plentiful in stands with low density (table 7). Ring counts showed that about 50 percent of the advanced oak seedlings were at least 6 years old and some were over 30 years old. A high percentage of all advanced pin and willow oak reproduction had died back previously, at least, once. Thus, they were actually seedling sprouts. The latter die back, and sprout again, from the stem at a point a few inches to a foot or more above the ground. This seemed to be a common occurrence for seedlings under the canopy. Like upland oaks the roots can exist for many years under the canopy, but net height growth of stems is practically nil. This agrees with findings on upland oaks (Merz and Boyce, 1956; and Piatnitsky, 1933). In the present case, at least, three consecutive years of winter flooding has not killed these seedling sprouts.

RESULTS ON THE FLOODED AREA

Acorn Production and Quality

In some respects, results on the flooded area were the same as on the normal area. The yearly trend in acorn production for both areas was strikingly similar, although actual production of sound, well-developed acorns was generally higher on the flooded area (table 4). Stand density and structure had about the same effect on acorn and seedling production as on the normal area.

The big difference between the flooded and the normal areas was in the quality of the acrons. The flooded area consistently produced a higher number and higher percentage of sound, undamaged, acorns (class 1) (tables 8 and 9). In 1957, the flooded area produced about 25 percent more class 1 acorns and the next year 15 times more class 1 acorns than the normal area. Both insect-infested and underdeveloped acorns were quite consistently more numerous on the normal area (table 8 and Appendix tables 13 and 14). In 1958, only 33 percent of the acorns on the normal area were sound, while on the flooded area 68 percent were sound. In 1957, sound acorns were 66 percent of the total on the normal area and 78 percent on the flooded area.

One reason for this difference could be the effect of flooding on the nut weevils (*Curculio* spp.). These weevils are by far the most important insects causing damage to acorns (Breznor, 1959). The females make the initial rupture in the seed coat and other insect larvae, as well as fungi commonly found in infested acorns, gain access through these breaks. *Curculio* are known to pupate in the ground over winter. McDermott and Enns (1957) have found that pupae can remain in the ground two years before emerging in late summer. Continuous flooding for three to four months in the fall and winter may have an adverse effect on these pupae and may account for the smaller proportion of insect-infested acorns on the flooded area (table 8). For example, during the 2 good seed years about three times as many acorns were insect infested on the normal as on the flooded area. It seems possible, however, that migration of *Curculio* from outside the 600-acre flooded area would tend to reduce any effect flooding might have on either their current or long-time population. It is perhaps also likely that the abundant soil moisture early in the summer on the flooded area was a factor that increased the numbers of well-developed acorns. At present, however, there is no direct evidence on this latter point.

Oak Reproduction

Apparently winter flooding was detrimental to new oak seedlings. By July 1959 the 1958 seedling crop amounted to 3,500 per acre on the normal area but only 56 on the flooded area despite the fact that there were more sound, undamaged acorns dropped on the flooded area. On the flooded area there was only one live seedling for every 2,100 class 1 acorns that dropped. On the normal area the ratio was one seedling to 26 class 1 acorns. Similar results occurred in the spring of 1959, although the poor acorn crop on the normal area in the fall of 1958 tended to obscure the effect (table 7). It was apparent that something happened to the acorns on the flooded area between seedfall and production of seedlings, or that something happened to the seedlings themselves.

Ground scarification on the flooded area had no significant effect on the establishment of oak seedlings. Oak reproduction was a failure on both scarified and unscarified portions of the plots.

TABLE 8-MEAN NUMBER OF ACORNS PER TRAP BY CONDITION OF ACORNS

Seed year	Class 1 Well-developed, sound, and undamaged		Class 2 Well-developed sound, and damaged		Class 3 Insect infested		Class 4 Underdeveloped or aborted		Total all conditions	
	Normal	Flooded	Normal	Flooded	Normal	Flooded	Normal	Flooded	Normal	Flooded
1957	3.35	4.25	3.46	3.02	1.16	0.27	2.38	1.75	10.35	9.29
1958	0.12	2.06	0.76	1.27	0.68	0.44	1.12	1.11	2.68	4.88
2-year total	3.47	6.31	4.22	4.29	1.84	.71	3.50	2.86	13.03	14.17

TABLE 9-NUMBER OF SOUND, WELL-DEVELOPED ACORNS* BY PLACES AND YEARS
(In thousands per acre)

Place and year	Undamaged	Damaged	Proportion undamaged
Normal area			
1957	92	96	49
1958	3.3	21	14
Flooded area			
1957	117	84	58
1958	57	35	62

* Class 1 and 2.

Advanced oak reproduction, established before winter flooding was started, was more plentiful on the flooded than on the normal area (table 7). This shows that winter flooding did not kill all established oak seedlings, two years of age or older, although some may have been killed.

MEANING OF RESULTS

This study revealed four important things about the seed production and regeneration of pin oak.

First, and probably the least surprising, is the fact that acorn production varies greatly by year. As in many tree species, seed production of pin oak is probably cyclic, although the present study was not long enough to ascertain any definite cycle. At any rate, it is plain that an extremely poor crop year can be followed by an extremely good one.

Because pin oak does not produce a good acorn crop every year, it is necessary to time regeneration cuttings to coincide with a good crop. Cutting during a poor seed year could result in poor regeneration of pin oak and prolific development of undesirable vegetation. This might greatly reduce the chances for establishing pin oak reproduction during subsequent good seed years. The best practice would be to cut either during the winter and early spring following a good seed year or cut one year after establishment of new reproduction. As pin oak requires two years to develop mature acorns, techniques for forecasting a good crop at least one year in advance of cutting can probably be developed.

Second, pin oak in pure, even-aged stands produces plentiful acorns, at least as early as the age range 25-35 years. This was the age of the stands in the present study. Stands with a relatively few large trees, up to 17 or 18 inches d.b.h., produced as many acorns as denser stands of smaller trees. However, stands with only 10 to 15 trees per acre 11 inches or larger, with no trees larger than 16 inches, produced more than enough sound acorns for reproduction. Thus, pin oak could be managed on a pulpwood or piling rotation, and the trees could be expected to reach sufficient size to produce plentiful acorns for regeneration. However, because pin oak is so intolerant, the silvicultural system used must be some form of clear-cutting, group selection, or shelterwood, as is true for any intolerant species. Cutting the first year after new seedlings are established would be ideal.

Third, during a good seed year the production of sound acorns is abundant. This means that reproduction after a good year will normally not be limited by a lack of sound acorns, even in low-density stands. In fact two and three years after cutting, stands with 40 square feet basal area produced nearly as many acorns as those with 60 and 80 or more square feet basal area. The good distribution of acorns in small openings (up to $^1/_{10}$ acre) showed that pin oak acorns are probably disseminated by the "whipping" action of trees in the wind as well as by the wind itself. Flood waters also distribute seed to some extent.

The great abundance of acorns in good seed years helps explain the frequent occurrence of dense stands of pin oak seedlings under pin oak, and the common occurrence under suitable conditions of dense, even-aged stands of pin oak.

Fourth, although the dormant-season flooding did not decrease the production of acorns, it did adversely affect the production of new oak seedlings (table 7). Possible reasons for this may be that: (1) the acorns may have deteriorated under the water during the flooding; (2) acorns may not have germinated or flooding may have caused unfavorable growing conditions for seedlings on the flooded area; (3) the winter flooding the first year may have killed the seedlings that became established; and (4) the acorns may have been consumed by waterfowl during the fall and winter.

That winter flooding may have killed the seedlings is not supported by the persistence of advanced reproduction established before winter flooding was started. However, the flooding may adversely affect one-year-old seedlings more than older ones. It is also unlikely that immersion in cold water even for three months will kill or even injure the acorns. In fact, immersion in cold water is recommended as a method of storing acorns (Toumey and Korstian, 1942). Also, pin oak acorns, stored in pond water from November until May, had high germination (Hosner, 1960). Furthermore, litter was only slightly thicker on the flooded area than on the normal area, but it may increase in thickness if annual flooding in continued. However, because disking and exposing mineral soil did not benefit seedling establishment on the flooded area, it does not seem logical that the lower numbers of pin oak seedlings on the flooded area can be attribued to the presence of slightly more litter. The possibility that acorns on the flooded area may have been consumed by waterfowl is a very real one and this factor will be discussed in a separate report.‡‡

This study indicates that areas artificially flooded every year during the dormant season may at some time require one to three years without floods in order to regenerate the area with pin oak. The withholding of water should be done after a heavy acorn crop in the fall. Such a treatment, however, would be required only infrequently, depending upon the silvicultural system used, unless continued annual flooding caused other damage to the stands.

‡‡The flooded area attracts thousands of waterfowl each fall and affords a good opportunity for such a study.

APPENDIX TABLES

TABLE 10-AVERAGE NUMBER OF ACORNS PER TRAP* BY PLOTS;** 1957 CROP; FLOODED AREA.

Plot †	Acorn Condition Classes X1 ††	Means	X2	Means	X3	Means	X4	Means
Ls-1	1.84	9.13	9.13		0.36		0.72	
Ls-2	2.76	2.49	0.92	4.14	0.36	0.27	1.04	0.84
Ls-3	2.86		2.36		0.08		0.76	
Ll-1	2.08		3.68		0.12		1.00	
Ll-2	4.08	3.27	1.96	2.05	0.32	0.23	1.00	1.15
Ll-3	3.64		0.52		0.24		1.44	
Ms-1	3.00		1.36		0.44		1.68	
Ms-2	3.60	3.43	0.72	1.77	0.24	0.31	2.08	1.91
Ms-3	3.68		3.24		0.24		1.96	
Ml-1	1.56		12.35		0.12		1.68	
Ml-2	7.33	5.27	1.00	5.01	0.12	0.20	2.44	1.86
Ml-3	6.93		1.68		0.36		1.47	
Hs-1	4.48		1.88		0.32		1.52	
Hs-2	4.66	4.82	1.36	3.00	0.32	0.39	1.28	1.96
Hs-3	5.33		5.76		0.52		3.08	
Hl-1	7.45		2.36		0.28		3.44	
Hl-2	6.00	6.20	1.60	2.17	0.00	0.20	3.12	2.76
Hl-3	5.16		2.56		0.32		1.72	
Ls-4	0.32		2.24		0.12		0.64	
Ls-5	0.56	1.01	2.40	2.97	0.36	0.32	0.64	1.19
Ls-6	2.16		4.28		0.48		2.28	
Ll-4	1.84		5.08		1.12		2.04	
Ll-5	3.00	2.41	4.88	4.21	0.84	1.03	1.32	1.59
Ll-6	2.40		2.68		1.12		1.40	
Ms-4	1.72		2.28		0.40		1.44	
Ms-5	1.64	1.63	4.76	2.80	0.48	0.39	1.92	1.48
Ms-6	1.52		1.36		0.28		1.08	
Ml-4	8.33		2.04		1.84		2.52	
Ml-5	3.92	5.14	4.32	3.05	2.48	2.00	3.28	2.67
Ml-6	3.16		2.80		1.68		2.20	
Hs-4	3.84		1.44		0.20		1.80	
Hs-5	2.92	3.99	1.52	2.13	0.88	0.73	2.04	2.24
Hs-6	5.20		3.44		1.12		2.88	
Hl-4	4.28		3.40		0.32		4.44	
Hl-5	8.73	5.92	8.84	5.61	3.80	2.47	4.48	5.11
Hl-6	4.76		4.60		3.28		6.40	

* Bushel baskets with diameter of 1.42 ft. Area = 1.58 sq. ft.
Conversion factor: Number per trap to number per acre equals 27,570.
Conversion factor: Number per trap to pounds per acre equals 67.24 (assumed 410 acorns per pound).

** One-half acre plots each with 25 traps mechanically space.

† L--low stocking s--small-tree structure
M--medium stocking l--large-tree structure
H--high stocking

†† X1 Well developed and sound
X2 Well developed but damaged
X3 Well developed but insect infested
X4 Underdeveloped, deformed.

TABLE 11-AVERAGE NUMBER OF ACORNS PER TRAP* BY PLOTS; 1958 CROP FLOODED AREA.

Plot	$\overline{X1}$	Means	$\overline{X2}$	Means	$\overline{X3}$	Means	$\overline{X4}$	Means
Ls-1	6.88		3.72		0.20		0.60	
Ls-2	0.92	2.89	1.64	1.92	0.40	.31	2.32	1.39
Ls-3	0.88		0.40		0.32		1.24	
Ll-1	2.00		1.16		0.48		1.44	
Ll-2	3.28	2.27	1.32	0.95	0.68	0.56	1.48	1.32
Ll-3	1.52		0.36		0.52		1.04	
Ms-1	0.68		0.16		0.24		1.36	
Ms-2	1.28	1.03	0.72	0.44	0.16	0.32	0.48	0.93
Ms-3	1.12		0.44		0.56		0.96	
Ml-1	0.08		0.24		0.04		0.24	
Ml-2	2.24	1.81	1.08	0.75	0.60	0.24	2.56	1.17
Ml-3	3.12		0.92		0.20		0.72	
Hs-1	1.36		1.00		0.52		1.28	
Hs-2	3.32	2.53	0.32	1.27	0.44	0.61	0.72	0.97
Hs-3	2.92		2.48		0.88		0.92	
Hl-1	2.52		4.84		0.84		0.84	
Hl-2	1.40	1.84	0.60	2.29	0.28	0.57	1.00	0.88
Hl-3	1.60		1.44		0.60		.80	
Ls-4	0.12		0.20		0.24		0.76	
Ls-5	0.00	0.05	0.32	0.20	0.20	0.24	0.52	0.55
Ls-6	0.04		0.08		0.28		0.36	
Ll-4	0.00		0.12		0.32		0.60	
Ll-5	0.04	0.25	0.92	0.81	0.96	0.71	1.72	1.15
Ll-6	0.72		1.40		0.84		1.12	
Ms-4	0.00		0.88		0.72		0.36	
Ms-5	0.00	0.00	1.68	1.01	0.80	0.73	0.92	0.75
Ms-6	0.00		0.48		0.68		0.96	
Ml-4	0.28		1.56		1.08		1.12	
Ml-5	0.28	0.21	0.44	0.87	0.96	0.83	2.28	1.68
Ml-6	0.08		0.60		0.44		1.64	
Hs-4	0.08		1.48		0.64		0.36	
Hs-5	0.00	0.04	1.40	1.05	1.00	0.99	1.24	1.09
Hs-6	0.04		0.28		1.32		1.68	
Hl-4	0.36		0.84		0.64		0.48	
Hl-5	0.04	0.15	0.44	0.63	0.40	0.55	1.72	1.49
Hl-6	0.04		0.60		0.60		2.28	

* Bushel baskets with diameter of 1.42 ft. Area = 1.58 sq. ft.
Conversion factor: Number per trap to number per acre equals 27,570.
Conversion factor: Number per trap to pounds per acre equals 67.24 (assumed 410 acorns per pound)

TABLE 12-TOTAL NUMBER OF ALL ACORNS PER ACRE AND PERCENT SOUND* AS RELATED TO YEAR, STOCKING-STRUCTURE AND FLOODING

Stocking and structure	1956 crop				1957 crop				1958 crop			
	Flooded		Normal		Flooded		Normal		Flooded		Normal	
	Number	Percent sound	Number	Percent sound	Number	Percent sound	Number	Percent sound	Number	Percent sound	Number	Percent sound
Low stocking					Number in units of 1000							
Low stocking												
Small	11	0	30	14	214	86	152	72	180	74	29	24
Large	14	2	82	18	185	79	254	72	141	63	80	36
Means	13	1	56	16	200	83	203	72	162	69	55	30
Medium stocking												
Small	26	1	24	3	206	70	174	70	75	55	69	42
Large	20	4	112	13	340	83	355	64	110	65	99	30
Means	23	2.5	68	8	273	77	265	67	93	60	84	36
High stocking												
Small	20	1	43	10	281	77	251	67	149	70	87	34
Large	28	3	80	11	313	74	527	60	179	78	78	28
Means	24	2	62	10.5	297	76	388	64	164	74	83	31
					Means structure classes							
All small structure	19	1	32	9	234	78	192	70	135	66	62	33
All large structure	21	3	91	14	279	79	379	65	143	69	86	31

*Class 1 and 2 acorns. Includes mechanical and animal damage but not insect infested or aborted acorns.

TABLE 13-DEFECTIVE ACORNS AS RELATED TO STOCKING-STRUCTURE AND FLOODING, 1957 CROP

Stocking and structure	Class 3; insect damaged		Class 4; under-developed		Total defective	
	Flooded	Normal	Flooded	Normal	Flooded	Normal
	Mean number per basket					
Low stocking						
Small trees	.27	.32	.84	1.19	1.11	1.51
Large trees	.23	1.03	1.15	1.59	1.38	2.62
Medium stocking						
Small trees	.31	.39	1.91	1.48	2.22	1.87
Large trees	.20	2.00	1.86	2.67	2.06	4.67
High stocking						
Small trees	.39	.73	1.96	2.24	2.35	2.97
Large trees	.20	2.47	2.76	5.11	2.96	7.58

TABLE 14-DEFECTIVE ACORNS AS RELATED TO STOCKING-STRUCTURE AND FLOODING, 1957 CROP

Stocking and structure	Class 3 insect damaged		Class 4 under-developed		Total defective	
	Flooded	Normal	Flooded	Normal	Flooded	Normal
	Mean number per basket					
Low stocking						
Small trees	.31	.24	1.39	.55	1.70	.79
Large trees	.56	.71	1.32	1.15	1.88	1.86
Medium stocking						
Small trees	.32	.73	.93	.75	1.25	1.48
Large trees	.24	.83	1.17	1.68	1.41	2.51
High stocking						
Small trees	.61	.99	.97	1.09	1.58	2.08
Large trees	.57	.55	.88	1.49	1.45	2.04

TABLE 15-MEAN NUMBER OF WELL-DEVELOPED, SOUND, UNDAMAGED ACORNS* PER TRAP AS RELATED TO TRAP POSITION; 1957 CROP

	Flooded			Normal		
Treatment	Under crown	Edge crown	In open	Under crown	Edge crown	In open
Low stocking						
Small trees	2.71	2.91	2.17	1.92	1.05	0.24
Large trees	6.08	3.79	1.61	1.50	4.53	1.00
Means	4.40	3.35	1.89	1.71	2.79	0.62
Medium stocking						
Small trees	4.14	3.50	2.12	1.66	2.29	0.47
Large trees	5.97	5.79	2.58	4.15	3.94	8.61
Means	5.05	4.65	2.35	2.91	3.12	4.54
High stocking						
Small trees	5.38	4.33	4.38	4.43	4.18	2.47
Large trees	8.65	5.39	3.20	6.13	6.78	4.11
Means	7.02	4.86	3.79	5.28	5.48	3.29
Means small tree structure	4.08	3.58	2.89	2.67	2.51	1.06
Means large tree structure	6.90	4.99	2.46	3.93	5.08	4.57

* Class 1

TABLE 16-MEAN NUMBER OF WELL-DEVELOPED, SOUND UNDAMAGED ACORNS* PER TRAP AS RELATED TO TRAP POSITION; 1958 CROP

	Flooded			Normal		
Treatment	Under crown	Edge crown	In open	Under crown	Edge crown	In open
Low stocking						
Small trees	1.36	1.86	3.98	.04	.14	0
Large trees	4.00	2.30	1.57	.50	.32	.09
Means	2.68	2.08	2.78	.27	.23	.05
Medium stocking						
Small trees	.93	1.27	.76	0	0	0
Large trees	1.85	2.36	.64	.30	.20	.11
Means	1.39	1.82	.70	.15	.10	.06
High stocking						
Small trees	2.54	2.53	2.50	.09	0	0
Large trees	2.28	1.75	.90	.12	.13	.22
Means	2.41	2.14	1.70	.11	.07	.11
Means small tree structure	1.61	1.89	2.41	.04	.05	0
Means large tree structure	2.71	2.14	1.04	.31	.22	.14

* Class 1

TABLE 17-MEAN NUMBER OF WELL-DEVELOPED BUT DAMAGED* ACORNS PER TRAP AS RELATED TO TRAP POSITION; 1957 CROP

	Flooded			Normal		
Treatment	Under crown	Edge crown	In open	Under crown	Edge crown	In open
Low stocking						
Small trees	5.00	3.90	3.95	3.42	4.32	1.59
Large trees	3.93	2.09	1.07	3.64	5.82	3.09
Means	4.46	3.00	2.51	3.53	5.07	2.34
Medium stocking						
Small trees	2.18	1.23	2.06	3.40	2.54	2.18
Large trees	6.00	3.39	5.94	4.30	2.80	1.61
Means	4.09	2.31	4.00	3.85	2.67	1.90
High stocking						
Small trees	3.33	3.50	.62	2.43	1.79	2.15
Large trees	2.75	1.72	1.80	5.77	7.22	2.56
Means	3.04	2.61	1.21	4.10	4.50	2.36
Means small tree structure	3.50	2.88	2.21	2.08	2.88	1.97
Means large tree structure	4.23	2.40	2.94	4.57	5.28	2.42

* Class 2. Does not include insect infested acorns

TABLE 18-MEAN NUMBER OF WELL-DEVELOPED, DAMAGED* ACORNS PER TRAP AS RELATED TO TRAP POSITION; 1958 CROP.

Treatment	Flooded			Normal		
	Under crown	Edge crown	In open	Under crown	Edge crown	In open
Low stocking						
Small trees	3.21	2.90	6.38	0.38	0.18	0.21
Large trees	5.43	4.24	2.18	1.14	1.54	0.64
Means	4.32	3.57	4.27	0.76	0.86	0.43
Medium stocking						
Small trees	1.21	1.90	1.12	0.87	0.55	2.06
Large trees	2.58	3.21	1.21	1.26	1.27	0.50
Means	1.90	2.56	1.17	1.07	0.90	1.28
High stocking						
Small trees	3.76	4.13	2.75	1.58	0.65	0.85
Large trees	4.24	4.44	2.70	1.08	0.69	0.50
Means	4.00	4.28	2.73	1.33	0.67	0.68
Means small tree structure	2.73	2.98	3.41	0.94	0.46	1.04
Means large tree structure	4.08	3.96	2.03	1.16	1.17	0.55

* Class 2. Does not include insect infested acorns.