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ILLINOIS NATURAL HISTORY SURVEY
HARLOW B. MILLS, *Chief*

Effect of
Permanent Flooding
in a River-Bottom Timber Area

LEE E. YEAGER

Printed by Authority of the
STATE OF ILLINOIS
ADLAI E. STEVENSON, *Governor*
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CONTENTS

In the Calhoun County, Illinois, study area, permanently flooded in 1938, pin oaks and other tree species having durable heartwood characteristically lost their branches and later their sapwood, leaving standing skeletons of heartwood.

Effect of Permanent Flooding

in a River-Bottom Timber Area

LEE E. YEAGER*

WATER impoundments, varying from simple fish ponds to the vast programs now being sponsored by the United States Corps of Engineers and the Bureau of Reclamation, involve many changes in the American landscape. Practically every major stream and hundreds of smaller ones have been or, if present proposals are consummated, will be affected by dams erected for power development, channel improvement, flood and erosion control, and other purposes. The environmental effects inherent in this nation-wide program are potentially of great importance to wildlife, inland fisheries, bottomland forests, and agriculture.

One of the problems associated with stream damming and resultant impoundments is that of flooded timberland. On many projects, especially where public funds are involved, the areas to be flooded are cleared of trees and brush. On others, clearing may be done only partly or not at all, because of shortage of funds, or because of bad weather, high water, or other reasons. Flood-killed timber is generally considered by the public as unsightly, and complaints concerning it may be strong. Dead trees that reach navigable streams after falling offer certain hazards to shipping, commercial fishing, and other enterprises associated with inland waterways. Therefore, whether from the standpoint of aesthetics or economics, flood-killed timber is a problem, and one having a strong probability of increasing in importance.

The objective of the study on which the present report is based was to determine the rate of flooding mortality in various Mississippi River valley tree species and the rate and effect of tree fall; in the course of the study, brief consideration was given to plant and animal succession following the death of timber stands. The report covers principally the period beginning in September, 1939, and ending in October, 1946.

* Formerly Forester, Illinois Natural History Survey, Urbana, Illinois. Since May, 1945, with the United States Fish and Wildlife Service; present station, Leader, Colorado Co-operative Wildlife Research Unit, Colorado Agricultural and Mechanical College, Fort Collins, Colorado. The major portion of the investigation on which the present paper is based was made while the author was employed by the Natural History Survey. Completion of the study was accomplished through a co-operative arrangement between the Survey and the Fish and Wildlife Service.

ACKNOWLEDGMENTS

My obligations for assistance during this investigation are many. I am indebted, first of all, to the late Dr. Theodore H. Frison, former Chief of the Illinois Natural History Survey, who proposed the study. To Dr. Leo R. Tehon, during part of the study period, Acting Chief of the Natural History Survey, and to Dr. Gustav A. Swanson, formerly with the Fish and Wildlife Service, I owe thanks for the co-operative arrangement wherein I was permitted to complete field observations. Dr. Tehon aided in planning the investigation and Mr. G. H. Boewe, also of the Survey staff, assisted with initial field work. Dr. Cornelius H. Muller, while with the Natural History Survey as a botanist, made the detailed vegetation map on which later work was based. For data used in preparing fig. 5, I am indebted to the St. Louis District, Corps of Engineers, Department of the Army. Several wildlife specialists of the Natural History Survey or co-operating organizations gave valuable help: Mr. Charles S. Spooner, Jr., was of much assistance in mapping; Mr. Frank C. Bellrose, Dr.

Ralph E. Yeatter, Mr. Harry G. Anderson, Mr. Charles McGraw, and Mr. Willet N. Wandell provided numerous records and were helpful in other ways; and Mr. Robert G. Rennels made careful analysis of food-habits material. Mr. Carl Pohlman, a resident of Calhoun County, gathered valuable records on the fur take. Mr. James S. Ayars, Mr. Robert E. Hesselschwerdt, and Dr. H. H. Ross, editor, photographer, and systematic entomologist, respectively, of the Illinois Natural History Survey, are responsible for most of the photographs used here as illustrations. Mr. Ayars' assistance with editorial problems is gratefully acknowledged.

AREA STUDIED

Detailed work forming the background for the present report was done on the Pere Marquette Wildlife Experimental Area, locally known as Calhoun Point, in Calhoun County, Illinois, fig. 1. Calhoun Point was formed by the confluence of the Mississippi and Illinois rivers.

At other than flood periods, previous to 1938, the 2,200-acre Pere Marquette area, roughly 1 by 4 miles, was characterized by numerous wooded ridges, flats, and wet-weather sloughs, several small lakes, a number of small marshes, and the margins of two large rivers. In June, 1938, gates of the recently completed Alton Dam, 20 miles downstream on the Mississippi River, were closed for the first time. This closure resulted in flooding several hundred acres of the area, normally land. Although the gates were opened a few times after June, 1938, the higher than normal water level that prevailed through much of the 1938 growing season, fig. 5, was sufficient to affect plant species sensitive to flooding.

By the summer of 1939, 600 acres (27 per cent) of the area were permanently inundated; 1,600 acres (73 per cent) lay above pool level, which was 15.3 feet

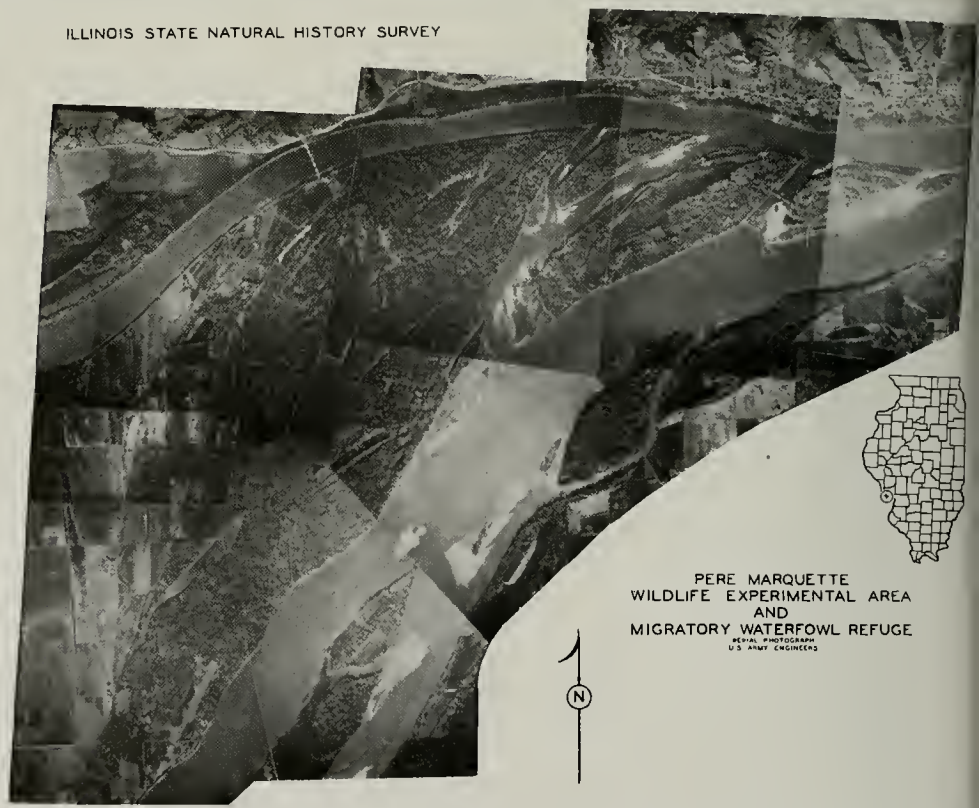


Fig. 1.—Air view of Calhoun Point, Calhoun County, Illinois, May 1938, prior to flooding.

at Grafton, 2 miles downstream. Prior to the Alton impoundment, annual fluctuation of the Mississippi and Illinois rivers in the locality varied from subgage lows to floods exceeding 25 feet. Even after the impoundment, severe floods occurred in 1943 and 1944 and a lesser flood in 1945. Permanent flooding increased the average summer water stage by about 3 feet. Maximum elevation on the area before impoundment was 10 feet; at pool level, after impoundment, the highest ridges were only 7 feet above the water surface. These figures indicate the very low relief of the Pere Marquette area.

STUDY PROCEDURE

Basic to the work reported here was a detailed vegetation map of the area prepared by Cornelius H. Muller while with the Natural History Survey's Section of Applied Botany and Plant Pathology. Muller did his field work between February 8 and June 11, 1938, shortly before initial flooding of the area was begun. In mapping the area, he established 11 transects, each 50 feet wide, that varied in length from 600 feet to 1.1 miles and totaled 5.9 miles.

Muller established the transects after he had made a general reconnaissance map of the many minor vegetation types distinguishable. He did not space the transects uniformly or orient them parallel with each other, but laid them out to cross as many as possible of the water channels and sloughs then present on the area and to traverse in a representative way as many as possible of the vegetation types.

He mapped the transects in such detail as to show the location of all trees, all large shrubs, and most of the herbaceous plant areas within them, recording species (substantiated by specimens deposited in the Illinois Natural History Survey herbarium), diameters of trees, sizes of shrubs, and density of herbaceous cover.

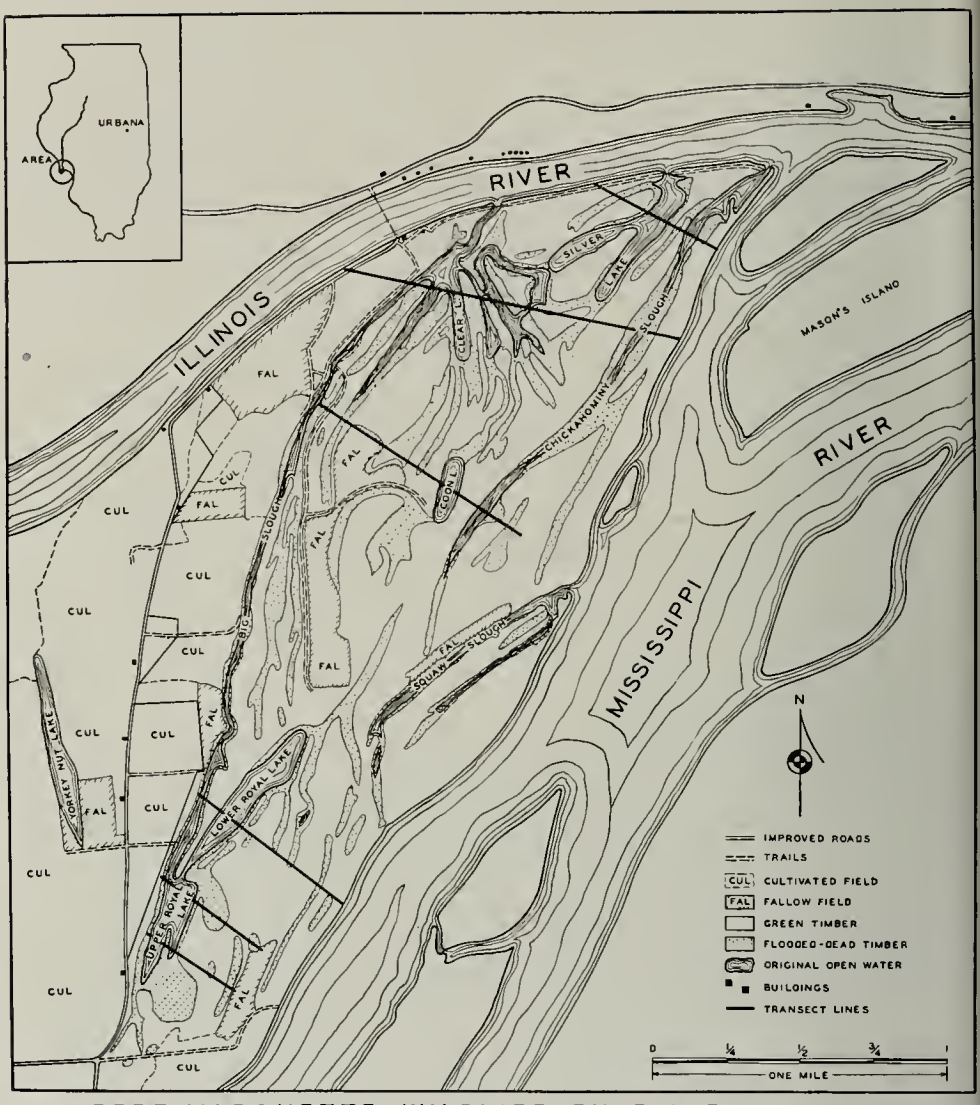
The location of six transects, 1, 2, 6, 7, 8, and 11, totaling 3.5 miles, is shown in fig. 2. These transects constitute the sample used as a basis for the present paper.

Active field work on the effect of flooding was begun in September, 1939, about 3 months after the date of permanent inundation. (The Alton Dam had been closed during the summer and a part of the fall of 1938, fig. 5.) The first records taken by the writer were before any of the trees had died, although the pin oaks and a few trees of other species showed effects of an abnormally high water stage.

In the six sample transects, 1, 2, 6, 7, 8, and 11, each living tree and shrub, regardless of species, size, or condition, was tagged for future inspection, except in pure stands of maple or elm on land, or in large clumps of waterprivet or buttonbush in water, where only every second, third, or fifth tree or shrub was tagged. Markers or tags were of 14-gage galvanized sheet metal, about 1 by 2 inches in size, each perforated at one end, and numbered consecutively. Attachment was by means of sixpenny galvanized nails, at a height of about 4.5 feet. In each transect the tags faced one direction, always that opposite to the direction of progress, thus facilitating both attachment and relocation. Transects were marked at each end and at varying intervals by appropriately numbered signs.

Records made at the time tags were attached and at all succeeding inspections were kept on the same form. At the first inspection, made when tags were attached, the number was recorded for each tree, and with it the tree species, d.b.h., crown class, and general vigor as near as this could be estimated. Where water occurred, the depth at the base of each tagged tree was recorded. At each succeeding inspection, the condition of the tree and the water depth, which varied as shown in fig. 5, were the main records taken. Trees obviously dying, but still with green leaves or cambium, were so recorded. Observations were made in June and October, 1940; one record was taken in June, 1941, one in October, 1942, and another in October, 1944, table 2. The final record was taken in October, 1946. A total of six inspections, in addition to those at the time of tagging and on numerous visits at other seasons, supplied data for this report.

Supplementing the detailed investigation in the Pere Marquette area were observations made in flooded areas along the



PERE MARQUETTE WILDLIFE EXPERIMENTAL AREA
GRAFTON, ILLINOIS

Fig. 2.—Land and water areas on the Pere Marquette Wildlife Experimental Area, Calhoun Point. Orientation of the six transects supplying sample data is shown by straight, heavy lines. The direction of flow of the Illinois and Mississippi rivers in this area is approximately northeast.

Mississippi River in Jo Daviess, Henderson, and Pike counties, and along the Illinois River in Mason and Jersey counties, all in Illinois. These areas were similar to Calhoun Point except that they were narrower, were bordered by large rivers along only one side, and supported greater proportions of willows and cottonwoods in the stands. The supplementary observations, confirmatory in nature, are not incorporated in this report.

Common and scientific nomenclature in this paper is, in most instances, based on the following authorities: Kelsey & Dayton (1942) for plants; Necker & Hatfield (1941) for mammals; American Ornithologists' Union (1931) for birds. Some forms were not identified to species.

TIMBER TYPES

Most of Calhoun Point, at the time of permanent flooding, was covered by river-bottom forest characteristic of that found in the upper Mississippi River valley. The stands, varying from sapling to mature growth, contained scores of very large, decadent, and often dying silver maples, with an occasional elm, sycamore, and pin oak of similar type, fig. 3. Composition, size classes, and the scientific names of all important trees and shrubs contained in the samples are indicated in table 1.

Silver or soft maple was the most abundant of the large trees in the flooded area. On the lowest level on which trees grew, it easily dominated all plants except semiaquatic species, such as black willow, buttonbush, waterprivet, and waterlocust, fig. 4. Many of the maple

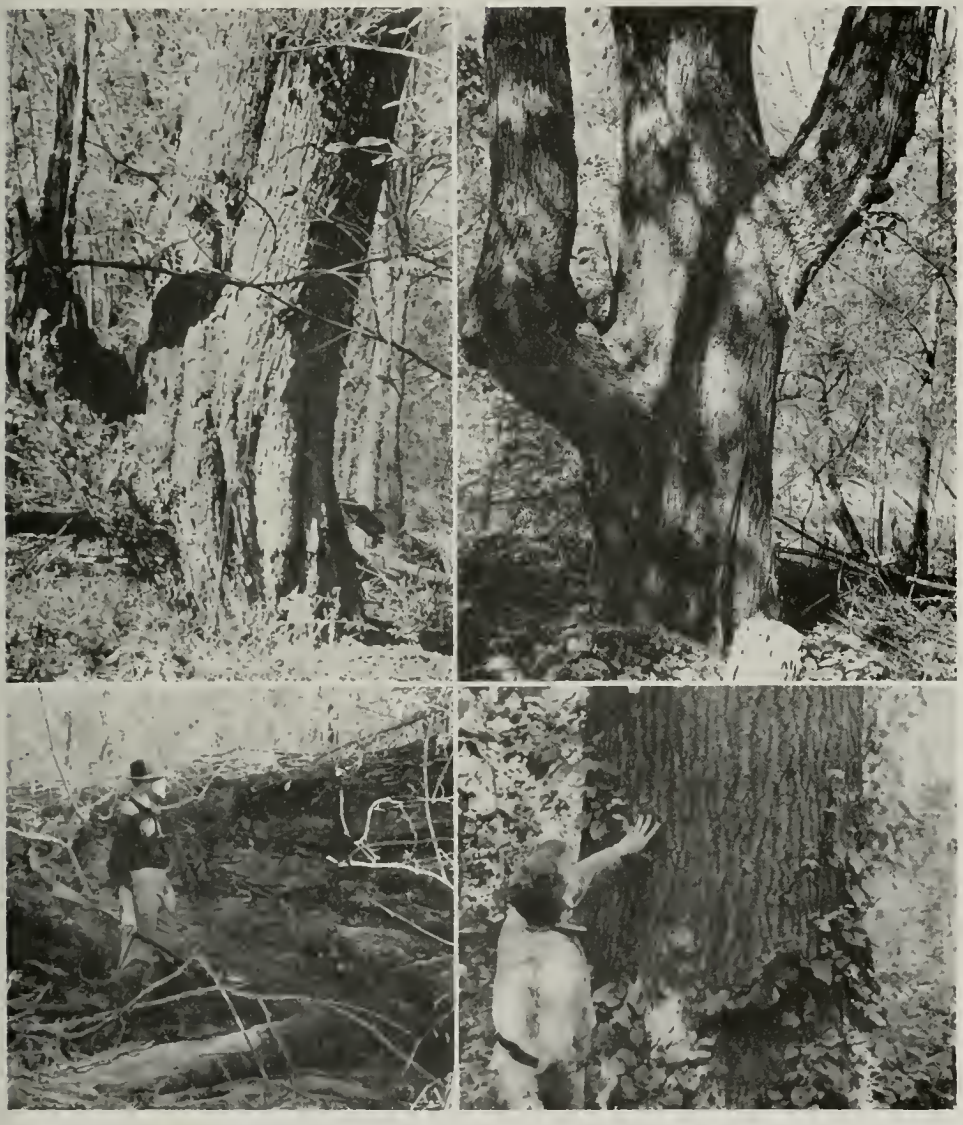


Fig. 3.—Huge, overmature, and characteristically multibranched maples, elms, oaks, and sycamores were found in the Calhoun Point stands, October, 1940.

Table 1.—Number of trees on land, in mud, and in water, in six 50-foot transects totaling 3.5 linear miles, in study area, Calhoun County, Illinois, October, 1939.

Species*	Diameter Classes, Inches																					Total			
	1–2			3–5			6–10			11–15			16–20			21–25			26 and over						
	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	Land	Mud	Water	All Trees
Maple, silver (*Acer saccharinum*)	0	1	0	9	6	21	69	17	43	93	16	40	26	6	38	0	2	17	19	7	18	216	55	177	448
Elm, American (*Ulmus americana*)	0	0	0	12	5	9	43	20	55	25	6	29	7	4	6	4	0	0	7	2	5	98	37	104	239
Ash, white (*Fraxinus americana*)	1	1	2	11	5	8	27	6	8	7	1	5	4	1	3	5	2	3	4	2	2	59	18	31	108
Oak, pin (*Quercus palustris*)	0	0	0	4	0	0	10	0	1	12	3	11	4	1	3	5	1	4	11	0	9	46	5	28	79
Pecan (*Carya illinoensis*)	0	0	0	2	0	0	10	0	3	17	2	15	14	0	6	2	0	1	1	0	1	46	2	26	74
Waterprivet (*Forestiera acuminata*)	6	2	22	12	3	24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	18	5	47	70
Persimmon, common (*Diospyros virginiana*)	0	0	0	5	1	7	6	1	14	16	3	13	0	0	1	0	0	0	0	0	0	27	5	35	67
Waterlocust (*Gleditsia aquatica*)	1	0	0	3	1	5	3	1	3	1	0	10	9	0	4	4	0	3	3	0	0	24	2	25	51
Hackberry, sugar (*Celtis laevigata*)	0	0	0	6	0	2	28	2	0	9	1	1	1	0	0	1	0	0	0	0	0	45	3	3	51
Hawthorn (*Crataegus* spp.)	0	0	0	10	2	5	6	1	7	1	1	4	0	0	0	0	0	0	0	0	0	17	4	16	37
Willow, black (*Salix nigra*)	0	0	1	0	0	4	0	0	13	0	0	4	0	0	1	0	0	0	0	0	0	0	0	23	23
Birch, river (*Betula nigra*)	1	1	0	1	1	1	0	0	4	1	0	4	1	0	5	0	0	2	0	0	1	4	2	17	23
Boxelder (*Acer negundo*)	1	0	0	1	0	0	9	0	0	8	0	0	1	0	0	0	0	0	0	0	0	20	0	0	20
Mulberry, red (*Morus rubra*)	0	0	0	6	0	0	8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	0	0	15
Buttonbush, common (*Cephalanthus occidentalis*)	0	0	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
Cottonwood (*Populus deltoides*)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	4	2	0	5	5	1	9	15
Holly (*Ilex decidua*)	3	1	7	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	8	15
Oak, bur (*Quercus macrocarpa*)	0	0	0	1	0	0	0	0	3	0	0	1	2	0	1	0	0	0	0	0	0	3	0	5	8
Sycamore, American (*Platanus occidentalis*)	0	0	0	1	0	0	1	0	0	2	0	0	0	0	0	1	0	0	1	0	0	6	0	0	6
Dogwood flowering (*Cornus florida*)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Plum, American (*Prunus americana*)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Elm, slippery (*Ulmus fulva*)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Coffeetree, Kentucky (*Gymnocladus dioicus*)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Redbud, eastern (*Cercis canadensis*)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	13	6	46	91	24	88	222	48	155	194	33	137	69	12	68	24	6	34	48	11	41	661	140	569	1,370

* Technical names from *Standardized Plant Names*, second edition, 1942; with few exceptions, common names from same source.

lats held standing water during the rainy easons. Maple was also a dominant pecies on some higher sites, including unlooded ridges. American elm, pecan, and ugar hackberry reached their best develpment at slightly higher elevations. Ash

The Pere Marquette area is north of the range of baldcypress and water tupelo *(Taxodium distichum* and *Nyssa aquatica)* and evidently of certain other southern river-bottom species, such as blackgum *(Nyssa sylvatica)*, American sweetgum

Fig. 4.—Typical stand of silver maple on a "flat" site, October, 1940. Dead and dying trees n background.

vas often found on lower sites occupied principally by maple, but occurred at all levations. Species of secondary impor ance on elm-ash-pecan sites included per immon, river birch, hawthorn, and holly.

On the highest land flooded, originally he lower ridges, pin oak, persimmon, cot onwood, and several less important pecies were found. Waterlocust grew nainly on shore lines but sometimes on idge sites; waterprivet and buttonbush were confined to shore lines and shallow loughs, both species often occurring in a oot or more of water. Found on unlooded land, particularly on the higher idges, were boxelder, red mulberry, redud, dogwood, American plum, honey locust, and Kentucky coffeetree, none of which appeared on the flooded portion of he samples, table 1.

(Liquidambar styraciflua), and the magnolias *(Magnolia* spp.), which were not represented. The area lies considerably south of the midwestern occurrence of tamarack *(Larix laricina)*, spruce *(Picea* spp.), balsam fir *(Abies balsamea)*, and northern white-cedar *(Thuja occidentalis)*. Black ash *(Fraxinus nigra)*, which occurs in Illinois, was not found in the area.

WATER LEVELS

That the water stage at Calhoun Point, even after closing of the Alton Dam, fluctuated considerably is shown in fig. 5. Fluctuation was due in part to winter drawdowns in 1938–39 and 1939–40, to unusually high floods during the springs of 1943 and 1944, and to a less severe flood in the spring of 1945. Several minor

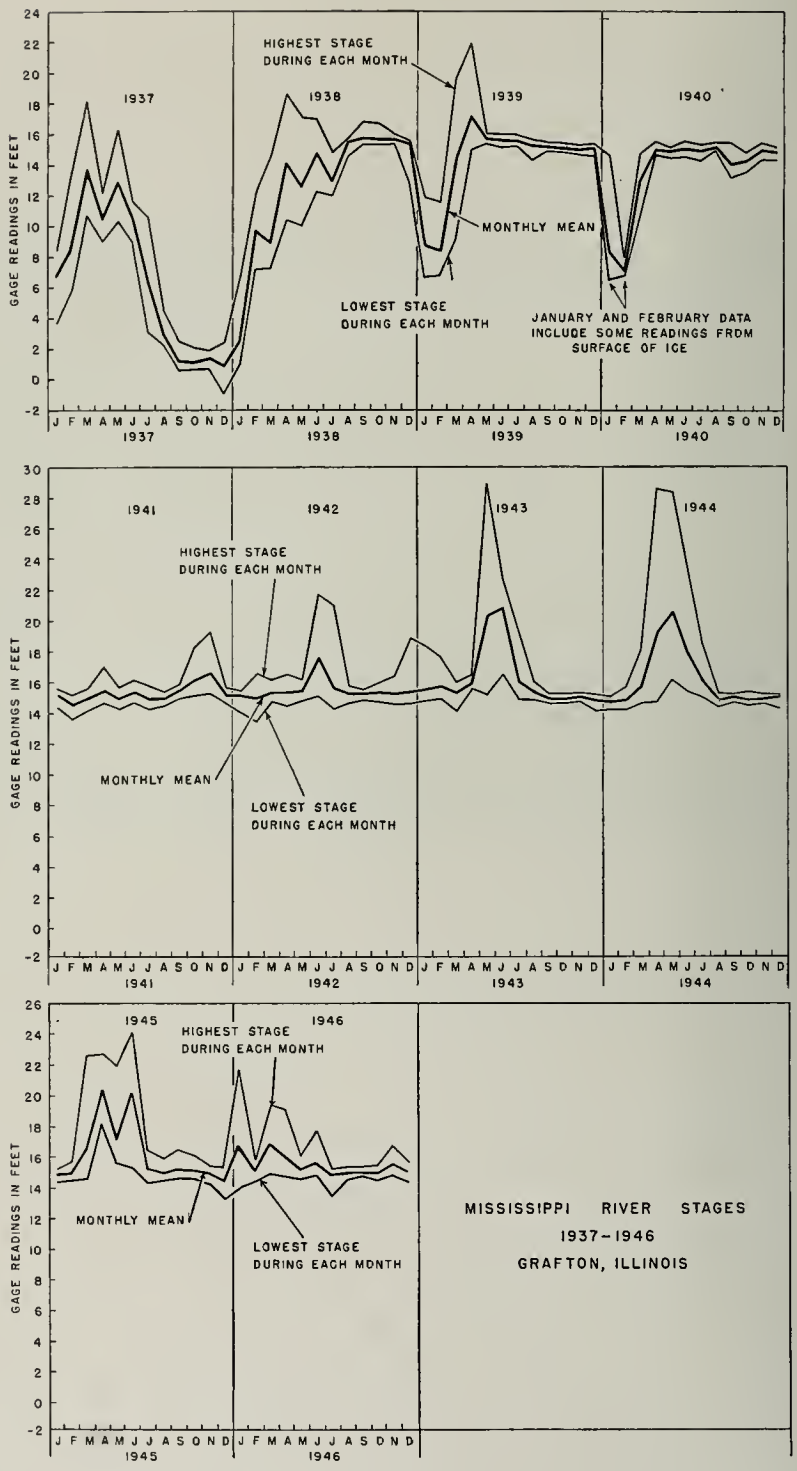


Fig. 5.—Mississippi River stages about 2 miles downstream from Calhoun County study area

fluctuations in water level came at other times. With the exception of the three spring floods, the more pronounced changes came during the dormant season and presumably had only a minor effect on woody species. The peaks of the 1943 and 1944 floods occurred during cool weather before the growing season was fully under way, at least for trees.

TREE MORTALITY

Although it is universally known that most trees and shrubs die when subjected to permanent flooding, the rate of dying, by species, diameter classes, and depths flooded, has received little specific study, and is not well known. Green (1947) reported on the only other study on this subject known to the writer. His work, also in the upper Mississippi River valley, covered the period 1939–1944.

Table 2 indicates roughly the rate of dying in common upper Mississippi River valley trees and shrubs in the Calhoun County study area, and tables 3 and 4 show the effect of flooding on these species by diameter classes and water depths, respectively. Trees indicated in the "land" classification were on unflooded area at pool stage; trees in the "mud" classification were well above the original permanent water level but, subsequent to flooding, mainly along the new shore lines and other low areas of muddy nature; trees in the "water" classification were entirely on newly flooded land, except for willow and buttonbush. These two species, therefore, did not occur in the "land" sample, nor did boxelder, red mulberry, and several less important species in the "water" sample. The effect of flooding on trees under "water," "mud," and "land" conditions is discussed below.

Trees Standing in Water

Virtually all trees permanently flooded to a depth of 20 or more inches were dead by 1946, 8 years after the initial impoundment, fig. 6. Species varied considerably in rate of mortality, table 2. Only

Fig. 6.—Most trees and shrubs flooded to depths above the root collar died in 1 to 6 years. Shown above is a waterprivet, relatively resistant to flooding, that died during the fourth year when flooded 20 inches. The large tree is a persimmon, which died during the second year. A heavy mat of duckweed covered the water in this area. The writer, taking notes, October, 1941.

Table 2.—Rate of dying of trees in six study transects, Calhoun County, Illinois, 1938–1944. Permanent flooding of area was begun in June, 1938.

Species	Trees on Land						Trees in Mud						Trees in Water					
	Number of Trees Tagged, October, 1939	Per Cent of Trees Dead					Number of Trees Tagged, October, 1939	Per Cent of Trees Dead					Number of Trees Tagged, October, 1939	Per Cent of Trees Dead				
		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944		June, 1940	October, 1940	June, 1941	October, 1942	October, 1944
Maple, silver	216	1.4	2.8	3.2	4.2	5.1	55	0.0	11.1	18 2	20.0	45.5	177	43.5	54.8	68.4	98.9	100.0
Elm, American	98	1.0	2.0	4.1	5.1	6.1	37	0.0	0.0	2 7	13.5	51.4	104	22.1	34.6	49.0	97.1	100.0
Ash, white	59	0.0	0.0	0.0	0.0	0.0	18	0.0	0.0	0.0	0.0	16.7	31	3.2	3.2	3.2	38.7	71.0*
Oak, pin	46	4.3	6.5	8.7	19.6	28.2	5	0.0	0.0	0.0	100.0	100.0	28	71.4	100.0	100.0	100.0	100.0
Pecan	46	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	100.0	26	23.0	42.4	61.5	88.5	100.0
Waterprivet	18	0.0	0.0	0.0	0.0	0.0	5	0.0	0.0	0.0	0.0	0.0	47	32.0	42.6	53.2	70.2	83.0†
Persimmon	27	3.7	3.7	3.7	3.7	3.7	5	0.0	0.0	0.0	0.0	80.0	35	22.9	42.9	48.6	100.0	100.0
Waterlocust	24	0.0	0 0	4.2	4.2	4.2	2	0.0	0.0	0.0	0.0	100.0	25	36.0	52.0	64.0	92.0	96.0
Hackberry	45	0 0	2.2	2.2	4.2	4.2	3	0.0	0.0	33.3	33.3	66.7	3	33.3	33.3	33.3	100.0	100.0
Hawthorn	17	11.7	11.7	11.7	11.7	11.7	4	0.0	0.0	0.0	75.0	75.0	16	56.2	81.3	81.3	100.0	100.0
Willow, black	0	—	—	—	—	—	0	—	—	—	—	—	23	13.0	17.4	21.4	39.1	43.5‡
Birch, river	4	0.0	0 0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	0.0	17	76.5	94.0	94.0	100.0	100.0
Boxelder	20	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Mulberry, red	15	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Buttonbush	0	—	—	—	—	—	0	—	—	—	—	—	15	20.0	26.6	40.0	53.3	60.0**
Cottonwood	5	0.0	0.0	0.0	0.0	0.0	1	0.0	0.0	0.0	0.0	0.0	9	11.1	44.5	66.7	100.0	100.0
Holly	6	0.0	0.0	0.0	0.0	0.0	1	0.0	0.0	0 0	0.0	0.0	8	25.0	25.0	37.5	100.0	100.0
Oak, bur	3	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	5	20.0	60.0	100.0	100.0	100.0
Sycamore	6	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Dogwood	2	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Plum, American	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Elm, slippery	1	0 0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Coffeetree	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Redbud	1	0.0	0.0	0.0	0.0	0.0	0	—	—	—	—	—	0	—	—	—	—	—
Total	661	1.4	2.3	3 0	4.2	5.3	140	0.0	4.3	8.6	17.9	45.7	569	33.7	47.1	58.0	88.8	93.5

* Sample indicated that 93 per cent were dead in 1946.
† Sample indicated that about 85 per cent were dead in 1946.
‡ Sample indicated that 61 per cent were dead in 1946.
** No sample taken in 1946.

Fig. 7.—Diameter of tree or shrub had little effect on survival after flooding except in semi-aquatic species and in reproduction sizes. In the area pictured above, all trees of 3 to 30 inches (larger trees in background) had succumbed by October, 1946, in 8 years of permanent flooding.

buttonbush, willow, and, to a less degree, waterprivet appeared to be adapted to conditions induced by impounded waters. Buttonbush did not succumb except where completely, or nearly, inundated. The few ash trees still living in October, 1946, were obviously dying.

Trees and shrubs of the various diameter classes showed little differentiation in survival ability after flooding except in the 2-inch class, table 3. In this class the difference was due to species (waterprivet and buttonbush, both semiaquatic) rather than to size, fig. 7. In general, healthy, vigorous trees of each species showed the greatest resistance to flooding, and the very small and the overmature classes of each species showed the least resistance.

Trees and shrubs still living and vigorous in 1944 were, in all cases, on the less deeply flooded areas; only waterprivet, buttonbush, and black-willow shrubs or trees still survived in water over 20 inches deep, table 4. More than half of the waterprivets and willows were dead by October, 1946. Before 1938, willows grew naturally in water or on the banks of sloughs and were flooded to greater depths than any other tree species; the depth averaged approximately 3 feet on the lower (northern) end of Calhoun Point. Had willows occurred in position to sustain all depths of inundation, a higher percentage of survival probably would have resulted. To all but semi-aquatic species, permanent flooding to a depth of 20 inches or less above the root collar was fatal.

Trees Standing in Mud

Trees in mud, in comparison with trees standing in water, showed a more or less

Table 3.—Mortality of trees, by diameter classes, resulting from permanent flooding of river-bottom timber in six study transects, Calhoun County, Illinois, 1938–1944.*

Species	Diameter Class, Inches																					Total		
	1–2			3–5			6–10			11–15			16–20			21–25			26 and over					
	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead
Maple, silver	0	—	—	21	21	100.0	43	43	100.0	40	40	100.0	38	38	100.0	17	17	100.0	18	18	100.0	177	177	100.0
Elm, American	0	—	—	9	9	100.0	55	55	100.0	29	29	100.0	6	6	100.0	0	—	—	5	5	100.0	104	104	100.0
Ash, white	2	2	100.0	8	5	62.5	8	7	87.5	5	4	80.0	3	1	33.3	3	1	33.3	2	2	100.0	31	22	71.0
Oak, pin	0	—	—	0	—	—	1	1	100.0	11	11	100.0	3	3	100.0	4	4	100.0	9	9	100.0	28	28	100.0
Pecan	0	—	—	0	—	—	3	3	100.0	15	15	100.0	6	6	100.0	1	1	100.0	1	1	100.0	26	26	100.0
Waterprivet	22	15	68.2	24	23	95.8	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	47	39	83.0
Persimmon	0	—	—	7	7	100.0	14	14	100 0	13	13	100.0	1	1	100.0	0	—	—	0	—	—	35	35	100.0
Waterlocust	0	—	—	5	5	100.0	3	3	100.0	10	9	90.0	4	4	100.0	3	3	100.0	0	—	—	25	24	96.0
Hackberry	0	—	—	2	2	100.0	0	—	—	1	1	100.0	0	—	—	0	—	—	0	—	—	3	3	100.0
Hawthorn	0	—	—	5	5	100.0	7	7	100.0	4	4	100.0	0	—	—	0	—	—	0	—	—	16	16	100.0
Willow, black	1	1	100.0	4	2	50.0	13	5	38.5	4	1	25.0	1	1	100.0	0	—	—	0	—	—	23	10	43.5
Birch, river	0	—	—	1	1	100.0	4	4	100.0	4	4	100.0	5	5	100.0	2	2	100.0	1	1	100.0	17	17	100.0
Buttonbush	14	8	57.1	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	15	9	60.0
Cottonwood	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	4	4	100.0	5	5	100.0	9	9	100.0
Holly	7	7	100.0	1	1	100.0	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	8	8	100.0
Oak, bur	0	—	—	0	—	—	3	3	100.0	1	1	100.0	1	1	100 0	0	—	—	0	—	—	5	5	100.0
Total	46	33	71.7	88	82	93.2	155	146	94.2	137	132	96.3	68	66	97.1	34	32	94.1	41	41	100.0	569	532	93.5

* See footnotes for table 2 regarding white ash, waterprivet, black willow, and buttonbush.

Table 4.—Mortality of trees, by depth flooded, resulting from permanent flooding of river-bottom timber in six study transects, Calhoun County, Illinois, 1938–1944.*

Species	Water Depth, Inches															Total		
	1–10			11–20			21–30			31–40			41 and over					
	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead	Number of Trees	Number Dead	Per Cent Dead
Maple, silver	57	57	100.0	71	71	100.0	33	33	100.0	12	12	100.0	4	4	100.0	177	177	100.0
Elm, American	56	56	100.0	40	40	100.0	6	6	100.0	2	2	100.0	0	—	—	104	104	100.0
Ash, white	17	9	55.5	7	6	85.7	2	2	100.0	3	3	100.0	2	2	100.0	31	22	71.0
Oak, pin	15	15	100.0	7	7	100.0	6	6	100.0	0	—	—	0	—	—	28	28	100.0
Pecan	7	7	100.0	16	16	100.0	3	3	100.0	0	—	—	0	—	—	26	26	100.0
Waterprivet	6	2	33.3	12	10	83.3	7	6	85.7	11	10	90.9	11	11	100.0	47	39	83.0
Persimmon	13	13	100.0	16	16	100.0	2	2	100.0	4	4	100.0	0	—	—	35	35	100.0
Waterlocust	4	3	75.0	10	10	100.0	6	6	100.0	1	1	100.0	4	4	100.0	25	24	96.0
Hackberry	2	2	100.0	1	1	100.0	0	—	—	0	—	—	0	—	—	3	3	100.0
Hawthorn	5	5	100.0	6	6	100.0	3	3	100.0	2	2	100.0	0	—	—	16	16	100.0
Willow, black	5	0	0.0	7	1	14.3	2	1	50.0	3	2	66.7	6	6	100.0	23	10	43.5
Birch, river	5	5	100.0	6	6	100.0	4	4	100.0	0	—	—	2	2	100.0	17	17	100.0
Buttonbush	3	0	0.0	3	1	33.3	2	1	50.0	1	1	100.0	6	6	100.0	15	9	60.0
Cottonwood	4	4	100.0	4	4	100.0	1	1	100.0	0	—	—	0	—	—	9	9	100.0
Holly	6	6	100.0	2	2	100.0	0	—	—	0	—	—	0	—	—	8	8	100.0
Oak, bur	0	—	—	2	2	100.0	1	1	100.0	2	2	100.0	0	—	—	5	5	100.0
Total	205	185	90.2	210	199	94.8	78	75	96.2	41	39	95.1	35	35	100.0	569	532	93.5

* See footnotes for table 2 regarding white ash, waterprivet, black willow, and buttonbush.

parallel, but less severe, mortality rate, table 2. In the transects selected for study, the number of trees in mud was small; also, the ultimate effect of mud, after 8 years, was less obvious than that of water, since reactions in this medium were slower.

In view of the small area of mud in the transects, supplementary observations were made in October, 1944. The data obtained vary from those of the transect samples only in method and places of collection. As presented in table 5, the supplementary data represent a special effort to enlarge the mud sample, particularly for cottonwood, birch, hackberry, persimmon, pecan, buttonbush, and pin oak. They were collected from strips running parallel to mud flats rather than at right angles to them. These parallel strips were near transects 1, 6, and 7, and were 30 to 50 feet wide; trees were taken in order of occurrence, regardless of species, size, or condition. It is believed that this procedure eliminated the error of selectivity, and, since the two sets of data show similar trends, together they give added reliability to the conclusions.

Raising of the water table so as to turn low ridges into mud flats resulted in timber mortality at the end of 6 years that ranged from 50 per cent to nearly 100 per cent, except for such species as privet, white ash, river birch, and cottonwood. The species best able to tolerate change of this kind clearly are waterprivet and buttonbush, as would be expected. By 1946, it appeared likely that a higher percentage of trees of all species would die in time, and that the mud flats would support cattail *(Typha latifolia)* or other marsh plants, or grow up to willow, cottonwood, white ash, and perhaps other forest reproduction, fig. 20. Extensive invasion of cattail, and, in some cases, arrowhead or duckpotato *(Sagittaria* spp.), fig. 8, had occurred prior to the extreme floods of April and May, 1943 and 1944, which destroyed most of them. In 1946, these marsh plants were reappearing.

In a study of the influence of flooding in upper Mississippi River pools, Green (1947) noted few deleterious effects on timber growing on land higher than the contour 2 feet above normal pool level. In the present study, the "mud" sample lay lower than the 2-foot contour, being in fact where the water table lay at or very near the ground surface. Green noted the appearance of forest reproduction on cleared area between pool stage and the 2-foot contour. Similar observations were recorded many times during the present investigation.

Trees Standing on Land

Even for land not actually flooded the water table was raised approximately 3 feet as a result of closing the Alton Dam.

Table 5.—Mortality in various species of trees on mud sites in study area, Calhoun County, Illinois, October, 1944. Permanent flooding of area was begun in June, 1938.

Species	Sample (From Table 2)		Supplementary Observations	
	Number of Trees	Per Cent Dead	Number of Trees	Per Cent Dead
Maple, silver	55	45.5	48	45.8
Elm, American	37	51.4	62	54.8
Ash, white	18	16.7	30	16.7
Oak, pin	5	100.0	25	96 0
Pecan	2	100.0	20	85.0
Waterprivet	5	0.0	17	0.0
Persimmon	5	80.0	23	78.3
Waterlocust	2	100.0	0	—
Hackberry	3	66.7	11	81.8
Hawthorn	4	75.0	6	83.3
Birch, river	2	0.0	10	20.0
Buttonbush	0	—	18	0.0
Cottonwood	1	0.0	18	27.8
Holly	1	0.0	0	—
Total	140	45.7	288	49.3

Fig. 8.—Cattail, rice cutgrass, duckpotato, smartweed, and other marsh or moist-soil plants invading timberland where the water table had been raised to the soil surface. Timber stand is dead or dying, October, 1941.

That timber stands were affected thereby was apparent, though not conspicuously so except in pin oak. This species, even on the unflooded land, suffered a mortality of 28.2 per cent by October, 1944, little more than 6 years after initial impoundment, and dying was noticeably progressive. Mortality in other common species was much lower, table 2. White ash, pecan, cottonwood, waterprivet, and several other species on unflooded land showed no loss as a result of the rise in the water table. Willow and buttonbush were not represented in the land sample.

By October, 1944, the two most numerous species on the area, silver maple and American elm, showed losses of 5.1 and 6.1 per cent, respectively, probably somewhat greater than natural mortality in stands where large poles and standards predominate. On land, the greatest loss in both maple and elm, as well as other species, was in the very large, overmature trees. The other common river-bottom species, persimmon, hackberry, and waterlocust, showed only slightly lower death rates than maple and elm. The death of two very large, old hawthorns, among 17 trees of this genus growing on land in the transects, is believed to have resulted from natural causes, rather than flooding, as other hawthorns growing outside of the transects were observed to be tolerant of the raised water table.

Discussion

Pin oak was easily the species most susceptible to injury by flooding, showing symptoms of dying as well as complete mortality before any other. Pin oak trees flooded in June, 1938, were clearly in a dying condition in September, 1939; by June, 1940, over 70 per cent had died, table 2. All were dead by October, 1940. In water, river birch indicated a slightly higher mortality rate than pin oak by June, 1940, but a somewhat slower dying rate thereafter. Pin oak trees in mud and on land sites with raised water levels died less rapidly than those in water, but all in mud succumbed before October, 1942, little more than 4 years after the original impoundment. A water table

raised to the ground level (trees in mud) was less injurious to river birch than to pin oak. Of the trees in water, hawthorn and silver maple, in June, 1940, were third and fourth, respectively, in rate of dying. The approximate number of years at which various species reached 100 per cent mortality is shown in table 6.

Fig. 9.—White ash was among the tree species most resistant to flooding. A few vigorous individuals, in less than 2 feet of water, threw trunk sprouts in 1946, during the ninth year of flooding. Two recently built duck blinds are shown in the center background.

Some pin oak trees died in 1 year, and other species showed high loss at least 1 year before the time of 100 per cent mortality. Most maples (98.9 per cent) and elms (97.1 per cent) were dead in little more than 4 years, table 2. Surviving white ash and waterlocust trees at the end of 6 years were so severely injured that few showed leaf in 1946. However, a few white ash trees showed small green trunk sprouts in October of that year. low, hackberry, privet, and buttonbush bore appreciable crops; and trees of maple, elm, ash, river birch, and pecan produced small crops. During the third year, willow, waterlocust, and waterprivet produced sparse crops and buttonbush a normal crop. Several persimmon trees growing on a steep-banked slough (Chickahominy, fig. 2) and with root systems inundated only on the lower or stream side, produced well in 1944. These trees died

Table 6.—Approximate period of flooding, up to 3 feet, required to kill all trees of various species in six study transects, Calhoun County, Illinois.

Two Years, October, 1940	Three Years, October, 1941	Four Years, October, 1942	Five Years, October, 1943	Six Years, October, 1944	Seven Years, October, 1945	Eight Years, October, 1946
Pin oak	Bur oak	Hawthorn	Silver maple†		Waterlocust‡	White ash**
	Hackberry*	Cottonwood	American elm†			Buttonbush
	Persimmon*	Holly		Pecan		Waterprivet††
	River birch*					Black willow††

* Listed as probable; all trees nearly dead at time of June, 1941, inspection; no check made in October, 1941.
† Listed as probable; no check made in October, 1945.
‡ Listed as probable; no check made in October, 1945.
** All trees virtually dead after 8 years; a few trees with small green sprouts on trunks in October, 1946.
†† Uncertain; some trees at edge of flooded area in shallow water still living.

These were young trees flooded to a depth of less than 2 feet, fig. 9. Waterprivet, buttonbush, and willow, all semiaquatic, survived in varying percentages. Invariably, living trees and shrubs in each species were those subjected to the shallowest flooding depths, in all except semiaquatic species less than 2 feet.

In summary, it may be said that flooding, under the conditions described, resulted in the death of most trees within a 5- or 6-year period. Although the effect of the three flooding conditions listed in table 2 differed only in degree in most species, several species, notably white ash, river birch, and cottonwood, were not greatly affected by a raised water table or flood-induced mud. These three species appear to be more tolerant of increased soil moisture than pin oak, American elm, pecan, persimmon, and others.

It was noted with interest that several species bore fruit under flooded conditions. During the second year after flooding, individual trees or shrubs of persimmon, hawthorn, holly, locust, cottonwood, willow, subsequently. Some pin oaks matured acorns in 1938, after being flooded temporarily in June of that year. No acorns were noted on flooded pin oaks in 1939, but they were observed that year on flooded bur oaks. Pin oaks on the highest land sites bore good crops in 1940, 1942, and 1944, but light to medium crops in the intervening years.

Differential rates of dying in parts of the same tree were commonly noted. This condition occurred where trees grew on the shores of steep-banked sloughs, in such position that the root collars were flooded on the stream side, but lay above the post-flooding level on the land side. Pecan, fig. 10, showed this differential dying phenomenon most frequently, but the same condition was noticed also in elm, cottonwood, and maple. A score or more of partly dead trees were observed on the banks of Big Slough in October, 1946; it seemed probable that most of these would die in time.

The setting of adventitious roots, particularly in willow, white ash, and buttonbush, and to a lesser degree in silver

Fig. 10.—Some pecans and other trees with root collar flooded on one side but above water level on the other side died first on the flooded side.

maple, was especially noticeable in 1939 and 1940. Such root growth was most pronounced near the new water line, but, in decreasing density, it extended down the trunk and thus for several inches below the water surface. This reaction of certain woody species to the stimulus of a raised water level is, of course, well known.

The effect of flooding on forest reproduction was similar to that in parent trees. An 8-acre clearing south of Sawmill Slough showed in 1938 a dense stand of seedlings, with some stump sprouts of elm, maple, and other species. In October, 1939, practically all of this reproduction except that of white ash and waterlocust showed evidence of dying; in October, 1940, all was dead except white ash in a foot or less of water. Even the +- to 6-foot ash seedlings succumbed where flooding occurred to a depth exceeding 12 or 15 inches. Of all species represented, ash reproduction showed greatest tolerance to permanent flooding.

TREE FALL

Tree fall in the following discussion refers to the dropping of branches as well as to actual fall of the tree, wholly or in part, in flood-killed timber as a result of death, decay, and wind action.

Rate and Manner of Falling

Falling of water-killed trees was not particularly noticeable until 1941, 3 years after the initial flooding. Prior to this time scattered trees and large branches had crashed, but this early fall was principally among the numerous large, multi-branched and decadent silver maples and small, badly suppressed trees of all species. Many of the large maples were 4 feet or more in diameter and some of them probably would have fallen if flooding had not occurred, fig. 3. By October, 1944, falling was more or less advanced in all species, indicating, as would be expected, rapid decay in this low, humid locality, figs. 11 and 12. Falling data are summarized in table 7.

Fig. 11.—Silver maple wind-thrown in 1940, about 2 years after initial inundation of the Calhoun County study area. Photographed in October, 1940.

The manner of falling in dead trees was confined to two general patterns, determined by the presence or absence of durable heartwood. Among the species having durable heartwood, pin oak was outstanding. Although the first to succumb to flooding, pin oak was the last to fall after death. Bur oak showed rather similar characteristics. Oak branches, particularly the larger ones, were slow to fall, since they contained a considerable volume of heartwood. In oaks, the sapwood decayed and fell usually off both trunk and larger branches, leaving standing skeletons of heartwood. Five years or more were required for this degree of decay. Dead oaks with sound wood were usually uprooted by winds rather than broken off, although in oaks weakened by advanced heart rot the reverse was true. Waterlocust, except for the larger trees, many of which were decadent, possessed strong heartwood and stood well. Branches of locust trees tended to fall after a year or two. White ash, with only fairly durable heartwood, and often with advanced heart rot in the larger trees, was intermediate in ability to stand.

There is a long list of river-bottom trees known to have quick-rotting heartwood. Most numerous of these trees on the study area were silver maple, American elm, pecan, persimmon, sugar hackberry, cottonwood, river birch, and willow. Of these species persimmon and overmature maple trees fell first. Multi-branched, spreading trees of all species characteristically lost their branches, leaving low, stubby, and often hollow snags. Vigorous maple, hackberry, birch, and willow trees were somewhat slower in falling, and all fell at about the same rate. Among species having nondurable heartwood, elm, pecan, and cottonwood were most resistant to falling. Cottonwood was surprisingly durable; mature trees dying in 1942 and possibly earlier were cut for lumber in the fall of 1944. Such trees, while having decayed sapwood, usually showed sound, though often stained, heartwood; they had been vigorous in life; and many of them were 2 and some 3 or more feet in diameter, fig. 13.

Table 7.—Degree of falling in river-bottom timber on six study transects, October, 1944 and 1946, Calhoun County, Illinois.* Permanent flooding of area was begun in June, 1938.

Species	Number of Trees Dead	Degree of Falling†											
		Main Branches On		Main Branches Off		One-Fourth Down		One-Half Down		Three-Fourths Down		Down	
		1944	1946	1944	1946	1944	1946	1944	1946	1944	1946	1944	1946
Maple, silver	232	64	4	23	22	30	45	52	68	24	38	39	55
Elm, American	141	74	9	29	18	10	38	18	32	2	14	8	30
Ash, white	49	37	8	0	12	0	8	4	5	0	4	8	12
Oak, pin	33	14	9	8	10	3	5	4	4	2	3	2	2
Pecan	28	3	0	11	8	6	10	5	6	2	2	1	2
Waterprivet	52	20	0	0	4	3	8	12	13	1	8	16	19
Persimmon	40	3	0	3	0	2	3	7	8	7	9	18	20
Waterlocust	27	6	1	10	9	2	8	4	4	1	1	4	4
Hackberry	6	2	0	2	0	1	4	0	1	0	0	1	1
Hawthorn	20	8	0	2	0	1	5	5	7	0	2	4	6
Willow, black	23	0	0	0	0	0	0	7	4	2	1	14	18
Birch, river	19	0	0	0	0	1	2	12	12	2	0	4	5
Buttonbush	15	3	0	0	0	0	0	3	0	0	5?	9	10?
Cottonwood	10	1	0	3	0	3	2	0	3	1	1	2	4
Holly	9	4	0	0	0	0	2	0	0	0	0	5	7
Oak, bur	5	0	0	0	0	1	0	3	2	1	2	0	1
Total	709	225	31	105	83	63	140	136	169	45	90	135	196

* Water and mud sites combined, tagged sample only. See text for discussion of 1946 data.
† "One-Fourth," "One-Half," etc., refer in each case to that portion of trunk broken off.

It was characteristic of species having nondurable wood to break off at varying distances above the ground; in such species, standing heartwood skeletons did not long remain, as they did in the oaks. Persimmons particularly showed a tendency to snap cleanly, leaving stubs ranging from 1 to 20 feet high. Maples that had been sound and vigorous, and all other central-stemmed species in the nondurable group, first lost their branches and soon afterward broke off at some point one-fourth to one-half way down from the top of the main stem, fig. 14. Decadent trees in this group tended to break off at some point of weakness, such as a rotted branch stub.

Although falling was not common until 1941, 3 years after permanent flooding was begun, it was so advanced in October, 1944, that travel in many places was not possible in a light canoe. A number of channels cleared prior to flooding were blocked in scores of places by logs and debris. Many areas that were maple flats and shallow sloughs at the time of flooding had become, at the end of 6 years, so many acres of stubs, varied in height and standing in shallow water that was clogged by a maze of fallen tree tops and trunks, fig. 15.

By October, 1946, approximately 8 years after permanent flooding was begun, tree fall had obliterated transect markings to such an extent that these lines could be followed only with difficulty where they crossed flooded areas. It was often impossible to find the metal tags with which sample trees had been marked. Some of these tags were undoubtedly buried on the undersides of fallen trees, in a foot or more of mud; others, presumably, had dropped off the rapidly decaying trunks and were lost in the mud and water below. For this reason, the entries under 1946 in table 7 do not have as high a degree of accuracy as the data for other years. The writer is confident, however, that the trend indicated by the 1946 data is not misleading, since falling was obviously far more advanced in October, 1946, than at the time of the 1944 inspection.

Fate of Fallen Trees

Most of the falls on Calhoun Point were in water. Many tops and branches

landed on end, becoming deeply embedded in the soft mud bottom. Many tree trunks, even when they fell in water deep enough to float them, became waterlogged and sank. Trees falling in shallow water, cottonwood and willow, are constant sources of river driftwood. Clearing of the shore lines appears to be the most practical method of reducing the amount of driftwood which, in navigable streams, is

Fig. 12.—Same log as in fig. 11, October, 1946. Dying in 1939 and falling in 1940, this maple showed advanced decay and disintegration, to be expected of nondurable woods in low, humid localities in the temperate zone.

unless held up by other falls, settled in the mud. Thus, logs and tops tended to remain on or very near the site of fall, or, if dislodged, were soon caught against the thousands of trees and stubs that covered the area. Comparatively few of these logs reached the Illinois and Mississippi rivers from the interior of the Pere Marquette tract, even during the severe floods of 1943 and 1944.

Many green or flood-killed trees that have grown along the shores of navigable streams are uprooted and swept into the main channels. Flooded, uncleared islands in the Mississippi River, covered mostly by an appreciable nuisance or even a hazard to river shipping and also to commercial fishing.

That few logs from Calhoun Point reached the Mississippi River was due to the fact that, prior to flooding, an extensive and thorough clearing operation had been performed along the Illinois River shore line. Much of the Mississippi River shore line at this point is low bluff, somewhat higher than pool stage. For this reason little or no tree mortality occurred from the rise in water level, and no dead timber from this shore reached the river channel.

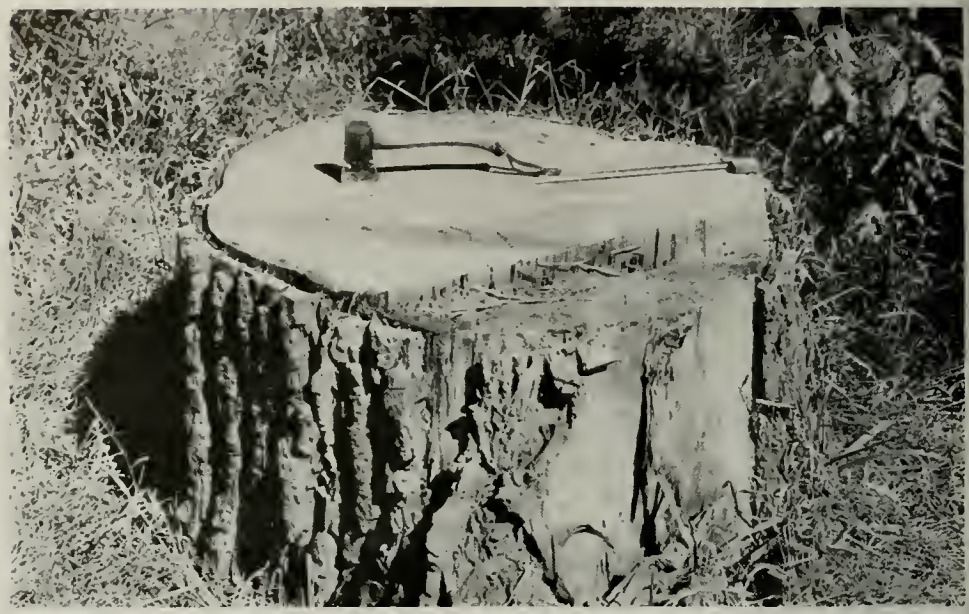


Fig. 13.—A 42-inch cottonwood flooded about 4 inches on the lower side in 1938. It died in 1942 and was cut for lumber in 1944. The heartwood was still sound but stained in October, 1946.

POST-FLOODING SUCCESSION

General, and for the most part incidental, observations on changes in plant and animal life subsequent to flooding were recorded during the investigation. Very profound changes are, of course, still in progress; this report is merely a summary of early succession phenomena.

Plants

The most conspicuous change in plant life was that of death in flooded timber. At the end of 8 years, most of the dead and fallen stand was in water less than 3 feet deep.

Conversion of much of this area, log-filled and snag-studded, to marsh was to be expected, and this transition had begun before 1946. Ecological development in the area following flooding may be ascribed largely to spread of plants already present and to introduction of seeds by water. As early as 1938, 2 years after excavation, borrow pits on the east end of the area supported vigorous stands of cattail *(Typha latifolia)*. By 1940, cattail stands had appeared in a scattered pattern on most of the water areas, as well as on wooded sites (timber dead) where the water table approached the ground surface, fig. 8. Stands of duckpotato *(Sagittaria* spp.) were particularly abundant along the lower end of Big Slough, where the channel had been deepened. Along the shore lines of both the Illinois and Mississippi rivers, rows of smartweed *(Polygonum* spp.) and cockspur or wild millet *(Echinochloa* spp.) appeared in both mixed and pure stands, undoubtedly due to the windrowing effect of wave action, fig. 16. Luxuriant growths of rice cut-grass *(Leersia oryzoides)* developed along the margins of many flooded areas in 1946, fig. 17.

Water in the sloughs and lakes, backwater in nature and without current except that induced by the rise and fall in pool levels, became progressively clearer toward the head of such bodies, even with the initial inundation in 1938. This condition permitted luxuriant growths of coontail or hornwort *(Ceratophyllum demersum)* and leafy pondweed *(Potamogeton foliosus)*, which became very noticeable in 1939 and reached their greatest development in

1942. Very heavy stands of sedges *(Carex* spp.) sprang up along some of the more open sloughs and shallow-water areas. The water supported a layer of duckweed *(Lemna, Wolffia,* and *Spirodela)*, commonly 1 inch thick, figs. 6 and 18. Filamentous algae covered every submerged object, fig. 19.

Extreme flood conditions during the early growing seasons of 1943, 1944, and 1945 had a profound effect on submerged and most emergent vegetation. The smothering effect of muddy, silt-laden flood water severely decreased the stands; during the summer and fall of 1943 and 1944, only scattered growths appeared; by 1945, all the plants mentioned above except duckpotato virtually disappeared from the area, but many of them had reappeared by the fall of the following year. Moist-soil species, particularly rice cutgrass, appeared in dense stands in 1946, probably from seed deposited by flood waters.

Forest reproduction, principally willow and cottonwood, appeared along the shore lines of the Mississippi and Illinois rivers as early as 1939, particularly where clearing had been done. Growth was vigorous in 1940. These species also appeared along the shore lines of the shallower and more open sloughs. Seeding was of course by wind and water from numerous parent trees still present on surrounding unflooded land.

On certain wet "flats," notably northwest of Lower Royal Lake and along part of the Illinois River shore line, silver

Fig. 14.—A silver maple stand, October, 1946, 8 years after inundation, showing falling and break-off characteristic of species having nondurable heartwood.

Fig. 15.—Silver maple "flat," flooded in 1938; a maze of fallen debris in October, 1946.

Fig. 16.—Stand of smartweed *(Polygonum* spp., chiefly *lapathifolium)* along the Illinois River on Calhoun Point, October, 1941. Seed presumably "windrowed" by wave action.

maple reproduction was abundant in October, 1944, reaching a density of four stems per square foot on small areas. White ash and American elm seedlings were common. Some pecan and pin oak reproduction was noted at various points. By October, 1946, practically all open, unflooded land supported a fair to full stand of river-bottom forest seedlings. Maple, elm, ash, willow, cottonwood, pin oak, and pecan reproduction was growing vigorously at this time; in some places it was as much as 10 or more feet high, fig. 20.

Mammals

Among mammals, muskrats *(Ondatra zibethicus zibethicus)* were most receptive to conditions brought about by permanent flooding of about one-fourth of Calhoun Point. In a complete coverage of the area in February, 1938, Frank C.

Fig. 17.—Rice cutgrass had attained luxuriant stands along the margins of flooded woodland in the study area by October, 1946.

Fig. 18.—Mat of duckweed an inch thick covered much of Royal Lake, Calhoun Point, October, 1941.

Fig. 19.—Filamentous algae grew in heavy mats over every submerged object, here revealed by a 16-inch drawdown, October, 1940.

Fig. 20.—Willow, cottonwood, elm, and silver maple reproduction on mud flat following death of most of the original stand as a result of flooding that raised the permanent water level nearly to the ground surface. A luxuriant stand of rice cutgrass grew between the bare mud flat and the forest zone in October, 1946.

Bellrose, Jr., of the Illinois Natural History Survey (personal communication) found no sign indicating the presence of these animals. In April of that year, temporary closing of the Alton Dam flooded the borrow pits and sloughs along the rivers, and within a few days muskrats appeared. Muskrat signs were fairly common on June 2, 1938, and in places abundant in October of the same year. Strong evidence was found during the next 3 years that muskrats were increasing in numbers. By October, 1940, muskrat cuttings (chiefly of cattails and sedges), droppings, and burrows were noted in or near practically every slough on the area, fig. 21.

The steady increase in numbers of muskrats in the Calhoun Point study area (Yeager & Rennels 1943) is reflected by complete or partial counts of trappers' catches for five seasons, as follows:

TRAPPING SEASON	MUSKRATS TRAPPED
1938–39	50–75
1939–40	225
1940–41	260
1941–42	350*
1942–43	400*

* Number does not represent a complete count.

The severe floods of 1943 and 1944 and a lesser flood of 1945 appeared to reduce the muskrat population appreciably, but muskrat signs were again common over much of the area in October, 1946. The destruction of cattail, coontail, and duckpotato by floods, as discussed under "Plants," probably accounted for seemingly increased use of sedges, smartweed rootstocks, and mussels late in 1944.

The effect of flooding on other fur animals of the study area is given in part by Yeager & Rennels (1943). Heavy trapping and loss of habitat, 1938–1940, resulted in decreased raccoon *(Procyon*

lotor) numbers during the next 2 or 3 years. However, this species, on Calhoun Point as elsewhere throughout its range, showed strong recovery by 1943. The raccoon population on the study area was high in 1944.

Opossums *(Didelphis virginiana virginiana)*, never heavily trapped or hunted after about 1939 because of low fur prices, remained numerous on Calhoun Point until 1943, when floods of that year and 1944 apparently reduced their numbers to a very low point. Astonishing as it may seem, not a single opossum track was seen during an inspection trip over the area that lasted from October 13 to 18, 1944, although special efforts under excellent conditions were made to find such tracks. No reason other than flooding can be given for the scarcity of opossums. These animals are good climbers but not good swimmers, and they do not possess marked ability to take food from water. Since the entire point was flooded to a depth of several feet in both years, opossums there were separated from land by flood waters for as much as 3 miles. Moreover, the floods reached their peaks during the young-rearing seasons. It is therefore not improbable that most of the animals, except those near the river bluffs, perished during the inundation. It should be remembered that, however well housed above the water level, any animal without food will find itself in dire straits before the end of a 2- or 3-week flood peak. Opossums showed some indication of coming back to Calhoun Point by October, 1946, but at that time they were far below their 1942 numbers.

Fig. 21.—Muskrat burrows under an old stump exposed by a drawdown of the water level of the Illinois River at Calhoun Point, October, 1940. The animals had attempted to plug entrances following exposure.

Minks *(Mustela vison)*, animals that are highly adaptable and equally at home on land or in water, were affected by the Calhoun Point floods less than any other fur species. Signs indicating substantial populations were noted during every year of the study.

Both red foxes *(Vulpes fulva)* and gray foxes *(Urocyon cinereoargenteus cinereoargenteus)* were present on Calhoun Point previous to the initial flooding in 1938. Flooding reduced the habitable area for both species, and the peak floods of 1943 and 1944 undoubtedly evicted

hem from the area. Abundant signs of oxes were never observed on the study rea after 1944, though fox density on djacent, but higher, areas remained at a ery high point for several years.

Striped skunks *(Mephitis mephitis)* ere more numerous in 1938 than at any ther time of the study. Even in that year ens appeared to be confined to the high- st ridge—the fallow field and the woods o the north of the field, both east of Big lough. Flooding and the resultant 3- oot rise in the permanent water level ndoubtedly made the area less suitable or this ground-denning species.

Woodchucks *(Marmota monax monax)* lso were adversely affected by permanent looding, although along the higher ridges heir dens and other signs were fairly com- non in October of 2 years of this study, 944 and 1946.

Calhoun Point has long been a favored ocality for squirrel hunters. Until about 940, gray squirrels *(Sciurus carolinensis)* redominated, as was attested by numerous unters. Fox squirrels *(Sciurus niger rufi- enter)*, until that time, were most com- non along the pin oak ridges bordering he large opening in the center of the area nd along Big Slough and the west bound- ry, both territories adjoined by cultivated ields. With the death of large tracts of looded timber and the resultant opening p of the stands, fox squirrels became the lominant species over practically the ntire area. In October, 1944, the writer overed every part of the 4-square-mile ract and observed a total of 24 fox squir- rels and 4 gray squirrels. Previously, the two species were more nearly equal in numbers.

Cottontail rabbits *(Sylvilagus floridanus)* were notably scarce on Calhoun Point, even before the 1943 and 1944 floods, which undoubtedly evicted them from the tract. They were more common along the inland boundaries of the area, and on adjacent farm land, a circumstance to be expected in view of the very low, wet nature of the greater part of Calhoun Point. Both food and nesting conditions on the study area were obviously less favorable than where waste grain, clovers, and other farm crops afforded abundant food, and higher sites provided safer nesting grounds.

Birds

Succession in bird life on this tract of flooded bottomland is indicated here only from general observations. Aquatic and marsh species, common before 1938, had become more numerous by 1944. Some indication of the increase is reflected in table 8, the data for which were taken from one 7-mile boat or canoe trip in each of 4 years on Big Slough, Royal Lake, Chickahominy Slough, and the Illinois River. The same route was followed at each observation. The general validity of the data in table 8 is strengthened by a number of other trips over the tract that yielded similar information.

Calhoun Point has been subjected to heavy duck hunting since 1938. One hun-

Table 8.—Numbers of birds observed on a 7-mile water trip through Pere Marquette study area in each of 4 years.

Species	Number of Individuals*			
	August 16, 1938	August 6, 1941	October 15, 1944	October 3, 1946
Wood duck	16	100	116	62
Black-crowned night heron	11	50	42	39
Yellow-crowned night heron	0	2	0	0
Great blue heron	6	10	22	19
American egret	6	68	40	31
Green heron	13	40	24	26
American bittern	1	2	0	3
Red-wing blackbird	10	56	40	24
Woodpeckers †	7	36	52	114

* All figures over 10 ending in "0" are estimates, believed to be conservative.
† Red-headed, pileated, flicker, downy, hairy, and red-bellied.

dred or more blinds scattered through the 4-square-mile area resulted in widespread shooting almost daily during each hunting season. Because waterfowl were thus discouraged during the fall in their attempts to use the new marsh and flooded woodland, evaluation of the area for waterfowl purposes has been complicated. However, the tract became potentially more attractive to dabbling ducks in its flooded state than it was formerly, because of the larger shallow water area and the development of rice cutgrass, fig. 17, smartweed, fig. 16, wild millet, and other aquatic and moist-soil plants that furnish food for ducks.

Wood ducks *(Aix sponsa)* are the only wild waterfowl that nested in the area. Yearly observations by Frank C. Bellrose, Jr., and other members of the Natural History Survey staff indicate a severalfold increase in breeding and summer populations of these birds since 1938, apparently because of the greater area of attractive habitat. Nesting sites in the hundreds of hollow snags and trees are ample; and quiet, duckweed-covered waters in the flooded timberlands are probably ideal as rearing grounds. There was some evidence in 1946 of decreasing attractiveness of the area to wood ducks as a result of the opening up of flooded woodland and the trend toward the marsh stage of succession.

There was abundant evidence during much of the study period of a general increase in number of herons on the area. After 1941, a score or more of these birds could often be counted at a single stand, and, by including all of the concentration areas on the point, 500 to 700 herons could easily have been recorded in a day's time. On August 6, 1941, Harry G. Anderson, an ornithologist associated with the Natural History Survey, and the writer counted 200 American egrets *(Casmerodius albus egretta)*, 12 snowy egrets *(Egretta thula thula)*, and 40 great blue herons *(Ardea herodias herodias)* on one 20-acre hay. None of these birds is included in table 8. In June, 1941, four green heron *(Butorides virescens)* rookeries, averaging 20 nests each, were found in the course of routine work. Systematic coverage of the tract would probably have disclosed others. The 600 or more acres of shallow water, abounding in minnows, small fish, frogs, crayfish, and other food, afforded excellent foraging grounds for all species of wading birds present.

With the appearance of marsh, breeding populations of red-wing blackbirds *(Agelaius phoeniceus phoeniceus)* became established in 1938. On May 15, 1942, Harry G. Anderson and the writer counted 22 red-wing nests in less than one-half acre of cattail marsh in Sawmill Slough, north of Coon Lake. This was near the middle of the area; other red-wing colonies were found in the various cattail stands along the Illinois River, Big Slough, and other places. The 10 red-wings noted on August 6, 1938, table 8, were in the vicinity of a cattail marsh at the mouth of Chickahominy Slough.

Highly suitable nesting and food conditions for woodpeckers were provided by the thousands of dead trees, in every condition of decay, on Calhoun Point. An increase of woodpeckers on the area was noticeable as early as October, 1939, following the death of numerous maple and other trees. As listed in table 8, at least six species were observed, of which the red-headed woodpecker *(Melanerpes erythrocephalus)* was most common. Next in numerical abundance was probably the red-bellied woodpecker *(Centurus carolinus)*; the flicker *(Colaptes auratus luteus)* was third. An unusual number of pileated woodpeckers *(Ceophloeus pileatus abieticola)* were present, the writer observing 13 on the morning of October 14, 1944. At least six were in one scattered flock. Downy *(Dryobates pubescens)* and hairy woodpeckers *(D. villosus)* were other species recorded.

No attempt was made to determine the effect of flooding on perching birds. Such conspicuous forms as the prothonotary warbler *(Protonotaria citrea)* and American redstart *(Septophaga ruticilla)* were abundant on the area in years covered by this report. Harry G. Anderson and the writer recorded 45 of the former and 30 of the latter on May 15, 1942. A total of 66 species of birds were listed on that date, but it is certain that many of these were migrants. General evidence indicates that the prothonotary warbler, at least, increased over the population present on the area is 1938.

Starlings *(Sturnus vulgaris vulgaris)* were observed in considerable numbers on the area in October, 1946.

SUMMARY

1. Timber killed by impoundment of water for power development, channel improvement, flood control, and other purposes represents a problem of growing importance throughout the United States.

2. The effect of water impoundment on timber was studied over an 8-year period, 1939–1946, at the junction of the Mississippi and Illinois rivers, where sizable tracts of river-bottom timber were killed by the Alton Dam impoundment, first pooled in 1938.

3. The study area, Calhoun Point, consisted of 2,200 acres of river-bottom forest, sloughs, lakes, and small marshes. About 600 acres of this tract were flooded permanently by the Alton Dam, which raised the average summer water stage about 3 feet. This rise in level reduced the highest elevation on Calhoun Point from 10 to 7 feet above the average summer water surface.

4. Timber stands on the study area were all-age, river-bottom hardwoods characteristic of the upper Mississippi River valley. Silver maple was easily the dominant species; American elm, white ash, pin oak, pecan, river birch, cottonwood, black willow, persimmon, hackberry, and waterlocust were other common species. Important shrubs were buttonbush, waterprivet, and deciduous holly.

5. The effects of flooding were studied on sample areas, consisting of six 50-foot transects, aggregating 3.5 miles in length. These transects crossed all representative timber types on Calhoun Point. Individual trees in the sample were identified by numbered metal tags attached with galvanized nails at breast height. Records involving species, d.b.h., crown class, general vigor, depth flooded, and year of death were taken at intervals. A total of six inspections, in addition to the one at time of tagging, and numerous visits at other seasons, supplied the data for this report.

6. River stages, 1937–1946, at Grafton, Illinois, less than 2 miles downstream from the area, were studied in relation to the rate of dying in tree species and succession in aquatic vegetation.

7. The effect of flooding on timber was studied under three categories: (1) timber actually flooded; (2) timber on sites where the water table had been raised to the ground surface; and (3) timber on unflooded land, where the average summer water table had been raised approximately 3 feet.

8. Eight years of actual flooding of timber areas resulted in practically complete tree mortality. In most tree species, flooding to a depth sufficient to cover the root collar, less than 20 inches, was fatal. Rate of dying showed wide variation by species. Pin oak was most susceptible to injury from flooding, all individuals of this species dying before or during the third year. White ash was most resistant, a few individuals giving rise to trunk sprouts 8 years after inundation. Mortality in most other tree species was 100 per cent in 6 years. Waterlocust showed a mortality of 96.0 per cent and black willow 43.5 per cent in 6 years; a few trees of these species were still alive 8 years after impoundment. All bur oak trees were dead 3 years after permanent flooding was begun; all persimmon, hackberry, hawthorn, river birch, and cottonwood were dead in little more than 4 years. Most silver maple was dead in about 4 years; all silver maple, American elm, and pecan were dead in about 6 years.

9. The three shrub (or small tree) species represented in the water sample likewise varied in tolerance to flooding. Deciduous holly showed 100 per cent mortality in about 4 years. Waterprivet, in October, 1946, more than 8 years after flooding, showed 85 per cent mortality; surviving individuals were in less than 2 feet of water. It appeared in 1946 that some of these would live. Buttonbush was definitely the most tolerant species sampled, this shrub showing a survival of 40 per cent or more except when deeply submerged.

10. The diameter of trees and shrubs subjected to flooding had little influence on their death rate. An apparent difference in the 2-inch class was due to species rather than to size. In general, within each species, healthy, vigorous trees showed the greatest resistance to flooding, and the

very small class (other than in semiaquatic species) and the overmature class showed the least resistance. The depth flooded (short of submersion) likewise appeared to make little difference, provided the root collar was covered. A depth of less than 20 inches was sufficient to cover the root collar of all species involved.

11. The harmful effect of a raised water table was clearly discernible, particularly where mud conditions were created, but, for each species, tree mortality was less severe in mud than in water. To mud, as to water conditions, pin oak was very susceptible and white ash very resistant; semiaquatic shrubs like waterprivet showed no mortality in mud.

12. On land above the mud level, but subjected to a 3-foot rise in the water table, only pin oak showed conspicuous reaction. Here, at the end of approximately 6 years, mortality among trees of this species had reached 28.2 per cent and was noticeably progressive. Losses in elm and maple were much lower, and white ash, pecan, cottonwood, and several other trees and shrubs apparently were unaffected by the increased water level.

13. Several tree species bore fruit under flooded conditions. This occurrence was most pronounced during the first 2 years. Only willow, waterlocust, waterprivet, and buttonbush produced fruit during the third year subsequent to inundation.

14. Trees with root systems flooded only on one side showed differential dying rates in parts of the same tree, the side inundated being nearly always the first to die.

15. Willow, white ash, and buttonbush showed marked ability to set adventitious roots during the first 2 or 3 years of flooding. Silver maple showed this ability to a lower degree.

16. The effect of flooding on forest reproduction was similar to that on parent trees. White ash reproduction showed by far the greatest tolerance to flood conditions.

17. Falling of dead timber became noticeable 3 years after flooding; it was advanced 6 years afterward, and extremely pronounced 8 years afterward. Pin oak showed greatest resistance to trunk fall; other species, without durable heartwood, snapped off at varying distances along the trunk.

18. Dead timber falling on the study area became waterlogged or deeply embedded in mud. Few falls reached the Mississippi and Illinois rivers to offer hazards to shipping and commercial fishing.

19. By 1946, conversion to marsh of the flooded bottomland, then a jumble of fallen logs and debris lying in mud and shallow water, had begun. Cattail, duckpotato, and various sedges were the most common marsh invaders; smartweed, wild millet, and rice cutgrass held a similar position on moist soil.

20. Extremely heavy growths of coontail and leafy pondweed, often covered in the fall by a mat of duckweed, appeared in the clear-water sloughs and lakes during the first 4 years of flooding.

21. Floods, several feet above normal pool stage in 1943, 1944, and 1945, destroyed practically all submerged and emergent aquatic vegetation, but, by the fall of 1946 several species showed evidence of recovery.

22. Reproduction of river-bottom tree species was common in 1944, and, in 1946, seedlings of maple, elm, ash, willow, cottonwood, pin oak, and pecan were growing vigorously.

23. Among mammals, muskrats showed great adaptability to conditions induced by flooding. The severe floods of 1943 and 1944, and a lesser flood in 1945, apparently depleted their numbers, but there was evidence of recovery by October, 1946. Opossums and cottontail rabbits were apparently evicted from the area by the series of high waters.

24. Raccoons and minks, with some fluctuations in populations, remained common to abundant in the area throughout the period of study.

25. Land mammals, such as woodchucks, skunks, and foxes, found less and poorer habitat on the area after flooding in 1938 than previously. The 3-foot rise in the water table undoubtedly limited the area suitable for ground dens on this low flood plain.

26. Flooding improved the Calhoun Point habitat for wood ducks, herons, and woodpeckers, and was attended by noticeable increases in the populations of these three groups. The increase was perhaps

most conspicuous in woodpeckers, for which the thousands of dead and dying trees provided unlimited food and nesting sites. The development of cattail marsh was accompanied by increases in the number of nesting red-wing blackbirds. Considerable numbers of starlings were observed on the area in 1946.

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