TREE MORTALITY CAUSED BY FLOODING AT TWO MIDWESTERN RESERVOIRS

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ABSTRACT

The effects of continuous spring and summer flooding on bottomland hardwoods at Rathbun Reservoir in southern Iowa and Carlyle Reservoir in southwestern Illinois were investigated. Substantial mortality occurred in nearly all species subjected to continuous flooding for 83 days after leafing out, 99 days after last freeze or a total of 129 days after the onset of flooding in mid-March.

The effects of inundation on trees has been a subject of numerous studies. Baldwin (1962), who reviewed several studies, generalized that trees subjected to brief annual inundation survived with no ill effects, while trees with root systems continuously inundated died. This general observation usually sufficed for practical management purposes, and many reservoirs have been constructed with the assumption that all trees left within the multi-purpose pool will eventually die. In most reservoirs, such trees were cut and removed from some zones prior to impoundment, but left standing in other continuously flooded zones to provide cover for fish after the trees died. However, in flood control reservoirs, there also is a zone (the flood pool) that is flooded only periodically. The size of the flood pool varies with the design of the reservoir. A substantial part of the flood pool usually is not cleared of trees, and the effect of periodic flooding on trees within this zone is important to managers of wildlife and other resources.

Five major reservoirs are under construction in Missouri at this time and others are in planning. Several thousand acres of riparian and bottomland hardwood stands will be included in the flood pools of these reservoirs, including portions of several wildlife management areas owned by the Missouri Department of Conservation. The purpose of this study was to assess the effects of inundation on forest stands in nearby locations and to identify problems requiring further research. The data will furnish guidance for administrative decisions concerning the management of forested lands on state management areas that may be subjected to flooding as well as to predict wildlife habitat losses from reservoir construction as a basis for mitigation.

Baldwin (1962) conducted an extensive review of the literature and cited 21 studies concerning the effects of flooding on trees. Tatter (1972) updated this review and cited 18 additional studies. We reviewed four additional studies, Anonymous (1973), Broadfoot and Williston (1973), Kennedy and Krinard (1974), and Bell and Johnson (1974) to provide background for this study. The results of these studies on the effects of flooding may be summarized as follows:

1. Tree species vary greatly in their tolerance to flooding. Trees that normally grow on wet sites are less likely to be damaged by flooding than those that grow on normally dry sites. Upland species will die the same year flooded if inundated long enough, whereas bottomland species may not die until the year following.

2. The season of flooding is extremely important. Dormant season inundation affects few trees, but nearly all species are killed if flooded for a long period during the growing season. The growing season was not defined specifically in most studies.

3. Trees entirely submerged are often killed or seriously injured. Thus, seedlings and low growing trees are more prone to damage than tall ones. Natural reproduction is made difficult or impossible under conditions of recurrent flooding.

4. Periodic flooding may be tolerated in varying degrees, depending upon the length of time the roots are continuously submerged. Repeated flooding may eventually cause decline and mortality of trees that survive occasional flooding.

5. Vigorous trees withstand flooding better than unthrifty trees.

6. Growth of trees may be reduced following flooding, but later returns to normal, or may even be stimulated.

7. In general, cold water is less injurious than warm water; clear water is less harmful than muddy water; and flowing water is less harmful than standing water.

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STUDY AREA AND METHODS

Two midwestern reservoirs constructed in recent years and containing stands of trees not killed by flooding before 1973 were selected for study. They were Rathbun Reservoir in south central Iowa, and Carlyle Reservoir in southwest Illinois. Both are multipurpose projects of the Corps of Engineers. Rathbun dam was closed in November 1969, and no significant flooding of the trees in the flood pool occurred during the growing season until 1973. During 1973, elevations above conservation pool were continuously flooded for various periods. Carlyle dam was closed in June 1967, and trees above conservation pool were flooded for significant periods during the 1970 and 1973 growing seasons.

Stands of bottomland hardwoods, particularly stands containing pin oak, were selected in the flood pool of each reservoir for study of mortality due to flooding. Trees were sampled at various elevations from the level where all trees were dead to the level where none were dead as a result of flooding. The elevation of the base of each tree was determined by measurements with level and stadia rod using the daily lake levels (elevations) reported by the project engineer's office.

All tree species encountered were included in the sample (see Tables 1 and 2 for lists of tree species involved and their scientific names). Data recorded for each tree included species, elevation, condition class, diameter at breast height (dbh), annual rings per last inch of diameter, position in stand and stocking level of the stand. The elevation of the soil surface overlaying the root zone of some trees varied one to four inches due to slope and irregularities of the soil surface. The median elevation was recorded, and subsequently lumped to the nearest increment used. All sizes of trees were included. Tree size ranged from 2 to 33 inches dbh with approximately one half of the trees sampled being larger than 11 inches dbh. Four positions in the stand were noted: (1) dominant, (2) co-dominant, (3) intermediate, and (4) suppressed. Growth rate was computed from rings per last inch and diameter at breast height. Trees that had died prior to flooding in 1973 were easily distinguished from trees that died in 1973-74 by the degree of deterioration of the bark and limbs and were not included in the sample.

RESULTS

Three measures of length of period of inundation were used to permit comparison of these results with results of other studies that variously used total inundation or an arbitrary date for growing season (Tables 1 and 2). For example, Hall and Smith (1955) used April 1 to October 1 as the growing season in Kentucky. Agriculturalists commonly consider growing season for crops as the period between last freezing temperature in the spring and the first freezing temperature in the fall (W. L. Decker, U. of Mo., Columbia, Pers. Comm., Oct. 21, 1974). In 1973, the last freezing temperature in the spring occurred on April 13 at both Rathbun and Carlyle Reservoirs. This was about two weeks earlier than normal at Carlyle Reservoir and four weeks earlier than normal at Rathbun Reservoir.

Table 1. Mortality by species and days inundated during the 1973 growing season on Rathbun Reservoir, Iowa.

Days of Continuous Root Inundation From March Through September 1973			Pin Oak (*Quercus palustris*)		American Elm (*Ulmus americana*)		Silver Maple (*Acer saccharinum*)		Swamp White Oak (*Quercus bicolor*)		Eastern Cottonwood (*Populus deltoides*)	
Total	After Last Freeze (4/13)	After Leaf Out (5/5)	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead
119	114	92					28	0			8	50
128	116	94	2	50			1	0				
133	118	96	4	0					3	100		
140	122	99	8	38	4	100	9	89	6	33	2	100
145	126	104	4	25					6	17		
148	128	106	35	80	6	83	6	83	1	100		
155	132	110	9	89	4	100	1	0	5	100		
161	136	114	5	100								
Total Trees Sampled			67		14		45		21		10	

[a]Mortality measured in September 1974.

Table 2. Mortality[a] by species and days inundated during the 1973 growing season on Carlyle Reservoir, Illinois.

Days of Continuous Root Inundation From March Through September 1973			Pin Oak (*Quercus palustris*)		American Elm (*Ulmus americana*)		Green Ash (*Fraxinus pennsylvanica*)		American Sycamore (*Platanus occidentalis*)		Shingle Oak (*Quercus imbricaria*)	
Total	After Last Freeze (4/13)	After Leaf Out (5/5)	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead	No. Trees	% Dead
123	95	79									6	50
126	97	81									5	80
129	99	83	3	67	1	0					8	100
139	108	92	3	67	3	33					2	100
140	109	93	2	100	2	0					3	100
146	114	98	4	0	1	0	1	100			1	100
152	119	103	7	43	2	50	2	0	1	0	2	100
158	124	108	4	25	3	33	1	0				
163	128	112	6	50	7	100	9	33	6	33		
168	132	116	9	78	2	100	3	67	1	100		
171	135	119	5	80	3	100	9	78				
192	155	139	5	100	1	100	3	100				
208	170	154	2	100	1	100	1	100				
Total Trees Sampled			50		26		29		8		27	

[a]Mortality measured in September 1974.

However, the effects of the earlier start of growing season, based upon the last freeze, was subsequently moderated by abnormally cool temperatures in April and May, particularly in west central Illinois. Trees undergo a period of very rapid height growth after they leaf out and photosynthesis begins (Kramer and Kozlowski, 1960). It is possible that trees may be less tolerant of flooding during the period of increased growth rate after leafing out. The period of inundation following leafing out is included for comparison with other factors. The dates of leafing out at each reservoir are based upon personal observations of the species studied. The effect of the deviation in temperature on the mortality rate of trees studied is not known.

Significant mortality of bottomland tree species occurred the year following inundation of their root systems for 99 days after the last freeze in the spring or 83 days after the trees leafed out (Tables 1 and 2).

Several trees that were classed as alive had only partially leafed out in 1974, but the leaves were still alive when measured in September, 1974. We expected that many of these would die in 1975, thereby increasing the mortality rates resulting from flooding in 1973. The stressed trees were not marked during this study for further observation. However, the magnitude of this stress effect demonstrates the need for studies to measure the long term effects of flooding. For example, at Rathbun Reservoir, of those trees classed as alive, 50 percent of the pin oaks, 33 percent of the swamp white oak, and 20 percent of the silver maple were so stressed.

Various analyses of the possible relationship of tree size, stocking level, position in the stand or growth rate indicated no likely trends worth pursuing.

CONCLUSIONS

At the reservoirs studied, continuous flooding of the root systems from the end of the dormant season to the first week of August caused significant mortality of bottomland tree species the following year and severely stressed many of the trees that survived. Flooding for an additional two weeks (to the third week of August) caused mortality of virtually all trees. We believe these results would apply to like situations in the central midwest. Willows, and other species adapted to wet areas, may be exceptions.

The reasons for the variations in mortality rates of each species between reservoirs for the same periods of inundation are not known. Deviations of the temperature from normal, previous flood effects, soil type and variations in the elevation of the soil surface under some trees may have contributed to the variations.

Obviously, the subject of this report merits further study. We need to understand how inundation affects the physiology of the trees causing mortality and, thereby, understanding the role of growing season and the effects of other factors to tolerance of flooding.

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