

FLOOD-CAUSED TREE MORTALITY AROUND ILLINOIS RESERVOIRS

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ABSTRACT

The effects of high reservoir levels in Rend Lake and Lake Shelbyville, both located in southern Illinois, on species of the streamside forest are described. Tolerances to growing season inundation for 24 tree species were determined from data on tree elevation and duration of flooding. A limit of 30 days of flooding during spring and summer months is suggested to insure survival of tree vegetation around reservoir margins.

INTRODUCTION

The impoundment of rivers and streams imposes stresses on the streamside forest community which were never experienced under natural conditions. The streamside plant associations develop in response to the complex of environmental factors which sorts out species that are intolerant of the existing conditions. Flood regime is the most determinant of the physical environmental parameters which control the distribution of tree species in the bottomland areas of the streamside forest (Bell, 1974). As water-resource development projects are established, the natural flooding characteristics of rivers are altered and the operation and management of reservoir levels can strongly affect organisms within its influence. Although the species distribution in relation to existing flood regimes can be a good indicator of flood tolerance, the distribution is probably a better indication of the tolerance of seed and young seedlings. Early stages of development are much more susceptible to the detrimental effect of flood conditions than are later stages (Lees, 1964). Protection of reservoir margin and riparian forests requires management plans which are based on the ecological tolerance of mature individual to water levels.

Timber clearing within the normal pool of a reservoir eliminates the problem of dying trees in the reservoir. Peripheral clearing may, however, be only partially completed due to shortages of funds, high water, wildlife preserves, or other reasons. Areas of bottomland timber upstream from the normal pool, but within the area influenced by operation of the dam, experience flood durations, frequencies, and magnitudes different from those under which these communities normally functioned. In areas surrounding the reservoir, upland forest communities which have rarely, if ever, experienced flood conditions may be subjected to environmental stresses resulting from flood water impoundment. Observation of the detrimental effects of high water on trees in previously established reservoirs can be extremely helpful in formulating operational guidelines for proposed or newly constructed impoundments.

The spring and early summer floods of 1973 produced abnormally high water conditions in the Lake Shelbyville and Rend Lake reservoirs in south

central and southern Illinois, respectively. Floods along the Mississippi River system prevented the reservoir managers from employing release rates sufficient to alleviate flooding conditions above the dam. Thus, many un-cleared areas above these reservoir dams were inundated for most of the 1973 growing season. The objective of the current study was to determine relationships between tree mortality and the period of inundation to better understand the ecological limits of tree species in the Midwest to flood conditions.

STUDY AREA AND METHODS

Sampling sites were established at three locations each on Rend Lake and Lake Shelbyville. Rend Lake is a multi-purpose project of the Corps of Engineers on the Big Muddy River in Franklin County near Benton, Illinois. Two of the Rend Lake sampling sites were located in Sec. 40 T4S, R3E, 3rd PM (Long. 88°55'W, Lat. 38°09'N), and the third in Sec. 4, T5S, R2E, 3rd PM (Long. 88°59'W, Lat. 38°07'N). Lake Shelbyville is a unit of the general comprehensive plan for the development of the Kaskaskia River Basin for flood control, water supply, fish and wildlife conservation, recreation, and downstream water quality control. It is located on the Kaskaskia River in Shelby and Moultrie counties near Shelbyville, Illinois. The three sampling sites were located within the Kaskaskia Fish and Wildlife Management Area, Sec. 16, T13N, R5E (Long. 88°40'W, Lat. 39°34'N).

Sites were chosen to incorporate both live trees and trees judged to have died within the 1973 growing season. Elevations of selected trees within each sampling site were determined by multiple foresights from a transit location in the center of the sampling site. Trees were chosen to fully represent the species and elevation diversity within the sampling site. Bench marks for the transit site were determined from elevations of the lake level on the sampling day and the season's highest water mark. From the daily lake level records and the elevation of the trees within the sampling sites, it was possible to determine the relationship between the length of the inundation period and tree survival. Nomenclature follows Jones (1963) except that Fraxinus pennsylvanica includes F. lanceolata.

RESULTS

Thirty-two species of trees were identified among the 671 trees sampled at Rend Lake and Lake Shelbyville. Of these, sample numbers for eight species were judged insufficient to determine their tolerance to flood conditions. Data on tree mortality in relation to flood duration are shown in Table 1. Within each flood-duration category, the percentage of flood-killed trees to the total number sampled provides the data to develop linear regression equations and describe the relationship between the length of flood duration and tree mortality.

Inundation of trees for less than 30 days during the growing season of one year was insufficient to kill any established tree. When flood durations reached 50 days, one of three Quercus velutina (Black oak) observed had not survived the flood conditions. Mortality among the predominately upland species became apparent when flood conditions extended to more than two months.

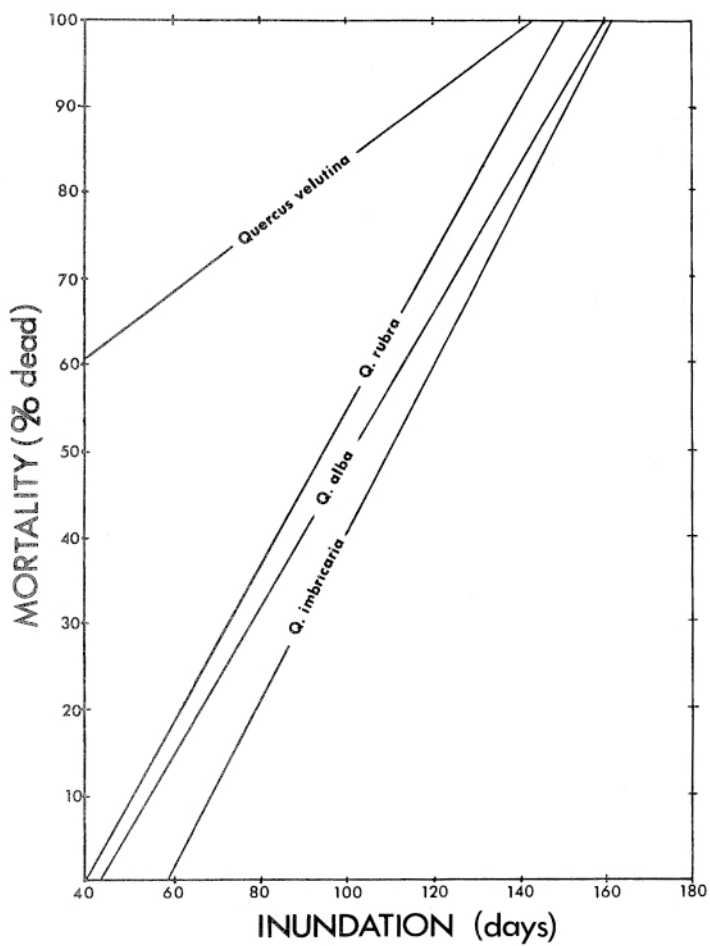


FIG. 1. Linear regression of percent dead vs. days of flooding for Quercus velutina, Q. rubra, Q. alba, and Q. imbricaria.

All Quercus velutina and Carya tomentosa (Mockernut hickory) found within the flooding increment receiving 70 days flood duration were dead and mortality was noted in Carya ovata (Shagbark hickory), Quercus alba (White oak), and Fraxinus pennsylvanica (Green ash). When the period of inundation reached 110 days, marked mortality was observed in the tree species normally associated with upland areas. These species include Quercus velutina, Q. rubra (Red oak), Q. alba, Carya tomentosa, Sassafras albidum (Sassafras), and Prunus serotina (Black cherry). Severe effects were also observed in Juglans nigra (Black walnut) and Quercus imbricaria (Shingle oak), species known to inhabit natural flood plains, but also occur more commonly on uplands. Effects of the impoundment were also noted in Carya ovata, Fraxinus pennsylvanica and Celtis occidentalis (Hackberry) at this duration. Increased flood duration resulted in increased mortality among upland species. Species of the flood plain, however, were found to be completely tolerant of the conditions imposed by the high water. Acer saccharinum (Silver maple), Salix nigra (Black willow), Populus deltoides (Eastern cottonwood), Acer negundo (Boxelder), Gleditsia triacanthos (Honey locust), and Quercus macrocarpa (Bur oak) showed no ill effects from up to 189 days of continuous inundation. Many trees of these species completed their annual growth cycle despite existing flood conditions throughout the growing season. At the time of the sample in late September, the bases of many of the trees were still under water.

Linear regression equations resulting in a statistically significant fit to the observed data were plotted to describe the mortality of the upland species (Fig. 1 & 2). The differential mortality of species within the genus Quercus was illustrative of the trends observed for all species (Fig. 1). Certain species were observed to tolerate flood conditions better than others. Within Quercus, Q. velutina was shown to be very intolerant to inundation; Q. rubra, Q. alba, and Q. imbricaria, less so, and Q. macrocarpa and Q. bicolor (Swamp white oak) were not adversely affected by the flood conditions (Table 1). A positive relationship between mortality and flood duration resulted within all species showing significant probabilities. A similar relationship of increasing percent mortality with increasing flood duration was observed in Carya with the predominately upland species C. tomentosa more susceptible to inundation than C. ovata which also occurs in areas of natural riverine flooding (Fig. 2).

DISCUSSION

The current study contributes to the knowledge of the interspecific difference in ability to tolerate flood. Information from the current and previous studies has been combined to group species of similar response to flooding (Table 2). It is apparent that species growing under conditions of periodic natural flooding are much more tolerant than those species which rarely or never are subjected to the stresses of high water conditions.

Quercus velutina proved to be the least tolerant to growing season flood conditions of all species observed in the present study. It was the only species to die from flood related causes generated by inundation of 30-49 days. No live Sassafras albidum or Prunus serotina were found at any

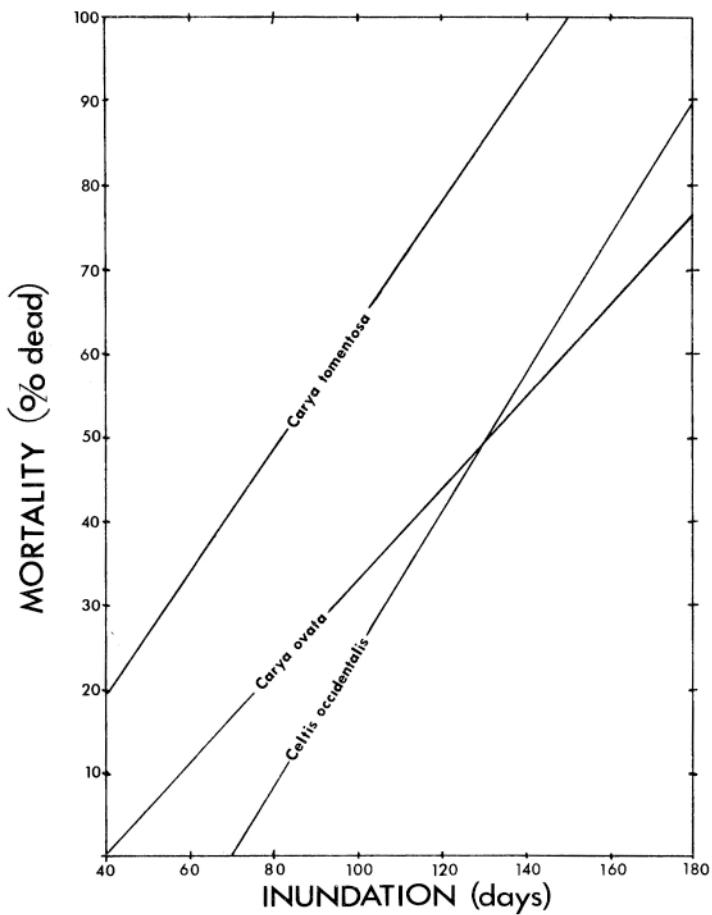


FIG. 2. Linear regression of percent dead vs. days of flooding for Carya tomentosa, C. ovata, and Celtis occidentalis.

TABLE 1. Mortality (% dead) of Illinois tree species to flood duration.
 Increments were no individuals of the species were found received no value (-).

Species	No. trees sampled	Flood Duration (days)								r ²	r	P
		30-49	50-69	70-89	90-109	110-129	130-149	150-169	170-189			
<u>Quercus velutina</u>	13	33	-	100	100	100	100	100	100	.498	.706	95%
<u>Quercus rubra</u>	16	0	0	0	100	100	100	100	100	.714	.845	99%
<u>Carya tomentosa</u>	47	0	0	100	65	100	100	100	100	.634	.795	95%
<u>Quercus alba</u>	58	0	-	17	46	83	100	100	100	.899	.948	99%
<u>Cercis canadensis</u>	13	0	100	0	33	-	50	100	-	.222	.471	N.S.
<u>Carya ovata</u>	114	0	0	33	43	31	44	92	62	.765	.875	99%
<u>Quercus imbricaria</u>	14	0	0	0	0	100	100	100	100	.762	.873	99%
<u>Juglans nigra</u>	4	0	-	-	0	100	-	-	100	.640	.800	N.S.
<u>Sassafras elbidum</u>	5	0	-	-	-	100	100	-	-	.964	.981	95%
<u>Prunus serotina</u>	3	-	-	-	-	100	100	-	-	-	-	-
<u>Fraxinus pennsylvanica</u>	115	-	-	50	92	39	32	19	18	.563	-.751	N.S.
<u>Celtis occidentalis</u>	37	0	-	0	0	33	45	93	100	.826	.909	99%
<u>Ulmus americana</u>	102	0	0	-	2	0	13	0	9	.297	.545	N.S.
<u>Quercus bicolor</u>	4	0	-	-	-	0	0	-	-	-	-	-
<u>Quercus macrocarpa</u>	13	-	-	0	-	-	0	0	0	-	-	-
<u>Dispyros virginiana</u>	5	-	-	0	-	0	0	-	-	-	-	-
<u>Gleditsia triacanthos</u>	26	-	-	-	0	0	0	0	0	-	-	-
<u>Quercus palustris</u>	4	-	-	-	0	0	-	-	-	-	-	-
<u>Crataegus mollis</u>	6	-	-	-	-	0	0	0	0	-	-	-
<u>Platanus occidentalis</u>	4	-	-	-	-	0	-	0	-	-	-	-
<u>Acer negundo</u>	6	-	-	-	-	-	0	0	0	-	-	-
<u>Populus deltoides</u>	7	-	-	-	-	-	0	0	0	-	-	-
<u>Salix nigra</u>	1	-	-	-	-	-	-	-	0	-	-	-
<u>Acer saccharinum</u>	39	-	-	-	-	-	0	0	0	-	-	-

TABLE 2. Flood tolerance of Illinois tree species.
Species are grouped in categories of increasing
tolerance to growing season inundation.

INTOLERANT SPECIES (severe effects with <50 days flooding)

Quercus velutina (Black oak)
Prunus serotina (Black cherry)
Sassafras albidum (Sassafras)

SLIGHTLY TOLERANT SPECIES (most individuals survive >50 days
but <100 days of flooding)

Quercus rubra (Red oak)
Quercus alba (White oak)
Carya tomentosa (Mockernut hickory)

SOMEWHAT TOLERANT SPECIES (some individuals killed by <90 days
flood and some individuals survived >150 days inundation)

Cercis canadensis (Red bud)
Juglans nigra (Black walnut)
Quercus imbricaria (Shingle oak)
Carya ovata (Shagbark hickory)
Celtis occidentalis (Hackberry)
Ulmus americana (American elm)
Fraxinus pennsylvanica (Green ash)

TOLERANT SPECIES (most individuals survived >150 days inundation)

Acer saccharinum (Silver maple)
Populus deltoides (Eastern cottonwood)
Platanus occidentalis (Sycamore)
Salix nigra (Black willow)
Quercus macrocarpa (Bur oak)
Gleditsia triacanthos (Honey locust)
Acer negundo (Box-elder)
Crataegus mollis (Red haw)
Quercus bicolor (Swamp white oak)
Diospyros virginiana (Persimmon)
Quercus palustris (Pin oak)

elevational increment receiving more than 50 days flooding. These species have been previously reported to be highly susceptible to flooding from reservoir inundation (Hall and Smith, 1955).

Quercus rubra, Q. alba, and Carya tomentosa were observed to tolerate 50 days of growing season high water but most succumbed to 100 days of spring and summer flooding. Briscoe (1957) noted the sensitivity to submergence of Quercus rubra and Williston (1859) observed that 60% of pole size or larger individuals of Quercus rubra and Q. alba were killed by 20 days of flooding. These results indicate considerably less tolerance to flooding of these species than found in our study. No previous reference to the tolerance of Carya tomentosa was found.

Several species showed moderate tolerance to growing season inundation. Quercus imbricaria was tolerant of over 100 days flooding but severe effects were noted when inundation continued for longer periods. Mortality was observed in Cercis canadensis, Juglans nigra, Ulmus americana, and Fraxinus pennsylvanica although mortality was not significantly correlated with length of the inundation. Percent normality of Carya ovata and Celtis occidentalis was positively associated with flood duration and most trees were unable to survive 150 days inundation. Most species within this group have wide distributions, naturally occurring in uplands as well as in areas of moderate flood regimes on the river flood plains (Bell, 1974). Fraxinus pennsylvanica and Ulmus americana (American elm) have been shown to withstand a shallow water-inundation period of about three months (DeGrunchy, 1956). Both species, however, were observed to suffer some ill effects of three-month floods at reservoir sites (DeGrunchy, 1959; Gates and Woollet, 1928) and to severe floods along river margins (Lentz, 1928). Intermediate responses to flooding for Ulmus americana and Celtis occidentalis were noted by Yeager (1949) for mature trees permanently inundated by closure of Alton Dam on the Mississippi River. No previous conclusions have been reported for the flood tolerance of Quercus imbricaria, Juglans nigra, or Cercis canadensis (Red bud).

The most tolerant species observed in the current study occur naturally in portions of the streamside forest which receive considerable inundation under normal river level regimes. Flood durations of 170 days during the rapid growth portion of the annual growing cycle was insufficient to visibly affect 11 species. The high degree of flood tolerance of many of these bottomland species has been noted previously (Green, 1967). Years of permanent inundation is sometimes required to cause death in these species. Yeager (1949) determined that two years would be required to kill all individuals of Quercus palustris, three years for Quercus macrocarpa and Glossyops virginiana, and longer durations for Populus deltoides, Acer saccharinum, and Crataegus spp. Salix nigra has been observed to survive up to 18 years of inundation (Eggleston and Moore, 1961).

The data collected in the current study would seem to indicate a limit of 30 days of flooding during the spring and summer to insure survival of upland tree vegetation. Flooding duration is only critical when the flooding occurs in the growing season. Flooding in the dormant season has little effect, even for long durations (Silker, 1948; and Hall and Smith, 1955). Repeated annual flooding during growing periods could result in

mortality of species with durations much less than those received in their first experience under reservoir conditions. Survival of even the most flood-tolerant of species requires at least 55-60% of the growing season to be unflooded (Hall and Smith, 1955). Mature, vigorous individuals suffer less flooding damage than do either seedlings or over-mature specimens of the same species (Chandra, 1965; and Lees, 1964). Stabilizing reservoir bank margins with seedlings of flood tolerant species could fail unless precautions are taken to markedly reduce flood period during early development of the trees. Reservoir management to protect the reservoir margin and upstream forests must be based on a knowledge of the limits of flooding tolerance for the tree species making up the forests.

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LITERATURE CITED

- BELL, D. T. 1972. How a dam may affect the environment. *Illinois Res.* 14 (2):10-11.
- BELL, D. T. 1974. Studies on the ecology of a streamside forest: tree stratum composition and distribution in the streamside forest. *Amer. Midl. Natur.* (in press).
- BRISCO, C. B. 1957. Diameter growth and effects of flooding on certain bottomland forest trees. Unpub. Ph.D. Dissertation, School of Forestry, Duke University.
- CHANDRA, L. 1965. Flooding: effects of flooding on trees. *Advancing Frontiers Plant Sci.* 12:161-180.
- DeGRUNCHY, J. H. B. 1959. Water fluctuations as a factor in the life of six of the higher plants of central Oklahoma. *Proc. Oklahoma Acad. Sci.* 37: 45-46.
- EGGLER, W. A., and W. B. Moore. 1961. The vegetation of Lake Chicot, Louisiana, after eighteen years of impoundment. *Southwest Nat.* 6:175-183.
- GATES, F. C., and E. C. Woollett. 1926. The effects of inundation above a beaver dam upon upland vegetation. *Torreya* 26:45-50.

- GREEN, W. E. 1947. Effects of water impoundment on tree mortality and growth. *J. For.* 45:118-120.
- HALL, T. F., and G. E. Smith. 1955. Effects of flooding on woody plants, West Sandy Dewatering Project, Kentucky Reservoir. *J. For.* 53:281-285.
- JONES, G. N. 1963. Flora of Illinois Ed. 3. Amer. Midl. Natur. Monogr. 7. 401 p.
- LEES, J. C. 1964. Tolerance of white spruce to flooding. *For. Chron.* 40: 221-225.
- SILKIN, T. H. 1948. Planting of water-tolerant trees along margins of fluctuating-level reservoirs. *Iowa State Coll. J. Sci.* 22:431-448.
- WILLISTON, H. L. 1959. Inundation damage to upland hardwoods. U. S. Forest Serv. South. Forest Exp. Sta. South. Forestry Notes 123.
- YEAGER, L. E. 1949. Effect of permanent flooding in a river-bottom timber area. *Bull. Illinois Natur. Hist. Surv.* 25:33-65.