Effect of greentree reservoir management on Mississippi bottomland hardwoods

Gary L. Young, Bob L. Karr, Bruce D. Leopold, and John D. Hodges

Greentree reservoirs provide flood control in the southeastern U.S. and habitat for migrating and wintering waterfowl. But how do these water management practices influence waterfowl habitat?

Greentree reservoirs (GTR's) are lowland forests wholly or partly enclosed by levees. These areas are generally flooded from late fall-late winter to early spring to provide habitat for migrating and wintering waterfowl, especially mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*).

Historically, naturally flooded hardwood bottomlands provided this waterfowl habitat (Fredrickson and Heitmeyer 1988), but clearing hardwood bottomlands for agriculture has reduced its availability (Fredrickson 1978, Harris et al. 1984). For example, 175,000 ha of hardwood bottomlands were lost yearly on average in the southeastern United States from 1960–1975 (Turner et al. 1981). Public and private land managers have used GTR management (Fredrickson 1980) to mitigate losses of hardwood bottomlands and waterfowl habitat.

Wildlife and forest managers are concerned about possible adverse effects of GTR management, including reduced regeneration of desirable mast and timber species, tree mortality, windthrow, and crown deterioration (Wigley and Filer 1989). Due to areas of high overcup oak (*Quercus lyrata*) seedling densities, managers of Noxubee National Wildlife Refuge (NWR) were concerned that 30 years of annual flooding in 2 GTR's was shifting composition toward flood-tolerant species. The large acorn of overcup oak is rarely ingested by waterfowl. Refuge managers also were concerned about the vigor and regeneration of desirable red oaks, especially cherrybark oak (*Q. falcata* var. *pagodaefolia*). Red oaks produce mast for waterfowl and are cut for lumber.

Because true treatment replication is lacking in most GTR studies, evaluating treatment effect among independent studies is important (Reinecke et al. 1989). Several studies have been conducted on the effect of GTR management on bottomland hardwoods in the Mississippi River Alluvial Valley (MRAV; Fredrickson 1979, Francis 1983). However, the hydrology, soil origin, and species associations of minor stream bottoms in Mississippi and elsewhere can be quite different from those in major river bottoms characteristic of the MRAV (Hodges and Switzer 1979). Additionally, evaluation of overstory composition in GTR's flooded nearly annually for >30 years is nonexistent. We evaluated the effect of GTR management on overstory, sapling, and seedling composition and density on a minor stream bottom site.

Evaluation sites

Our study was conducted at Noxubee NWR in east-central Mississippi (33°17′N, 88°45′W). Study sites were GTR's 1 and 2 and an adjacent, undiked hardwood bottomland that served as a control (Fig. 1). The control area floods naturally from overflows of the Noxubee River but is otherwise similar to GTR's 1 and 2. GTR's 1 (154 ha) and 2 (121 ha) were con-

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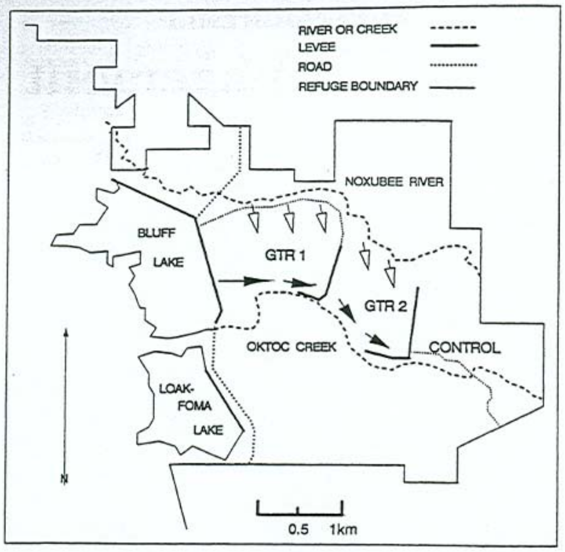

Fig. 1. Study area and waterflow patterns, Noxubee National Wildlife Refuge, Mississippi, 1988–1989. Open arrows indicate overflow route of the Noxubee River; solid arrows indicate flow via creeks and sloughs from Bluff Lake.

structed in 1955 and 1958, respectively. When flooded during winter, Noxubee GTR's were flooded from November until drawdown, beginning by 1 March. The primary water source for both GTR's was Bluff Lake (486 ha), which was adjacent and west of GTR 1. Bluff Lake was constructed in the 1930's.

Both GTR's were flooded annually through 1985, except winter of 1979–1980. Because of concerns about changing tree species composition, a 2-year winter flooding regime was initiated in 1985. When GTR 1 was flooded during winters 1985–1986 and 1986–1987, GTR 2 was not flooded. GTR 2 was flooded during winters 1987–1988 and 1988–1989. Although inundation was not scheduled, GTR's flooded periodically during winter, spring, or summer from Noxubee River overflow. For example, Noxubee River flooded GTR 2 during winter 1989–1990 and GTR's 1 and 2 five times during spring and summer 1989 for about 5–7 days.

Assessing site characteristics

Sampling periods and sites

We sampled overstory and first-year seedlings during summer in 1988. Sapling and second-year seedlings were sampled during summer in 1989. North–south transect lines (5 km in each study site) were located 200 m apart. Because boundaries of each study site varied, 5, 7, and 9 lines were contained in the comparison area, GTR 1, and GTR 2, respectively. Fifty permanent sampling points were located 100-m apart along transect lines in each study area.

Vegetation measurements

Tree species composition, density, and basal area were determined using the point-center quarter method (Cottam and Curtis 1956). Diameter at breast height (dbh) and tree species (dbh ≥ 10.5 cm) nearest the sample point in each quarter were recorded. Seedling (height 1 m) composition and density were sampled using a 2-m radius plot centered on each sample point. Sapling (height >1 m) composition and density were sampled using a 20 x 2-m plot at each sample point. Sapling plots were located by centering the south 2-m side on the sample point.

Canopy openness at each sample point was measured using a spherical densiometer (Strickler 1959). One reading was taken in each cardinal direction; the 4 readings were averaged to estimate canopy openness at the point.

Data analyses

Species importance value indices were used to compare vegetation composition among study sites (Curtis and McIntosh 1951). Importance values were the sum of relative frequency, density, and dominance (overstory only), and therefore indexed the relative contribution of a species to the community (Barbour et al. 1980:170).

Because winter flooding treatment was not replicated, inferential statistics were used to test for differences among sites only and not flooding effect (Guthery 1987). Use of inferential statistics in tree density and basal area analyses was not possible using the point-center quarter method because values were computed from the average distance of sample trees from the sample points.

Seedling and canopy data were transformed to stabilize variance among sites (Steel and Torrie 1980:234–235). Data on seedling density and canopy openness were transformed using the following equations:

$$\sqrt{(n \text{ seedlings/plot}) + 0.5} \qquad (1)$$

$$\sqrt{(100\% - \text{canopy density}) + 0.5} \qquad (2)$$

Transformed values were backtransformed and presented as means with 95% confidence limits.

Canopy openness and differences in seedling and sapling densities among study sites and between years were tested using 1-way analysis of variance (ANOVA, SAS Inst., Inc. 1985). Duncan's multiple-range test was used to separate means.

Site composition and response

Stand composition and tree size

Overstory tree species composition differed among study sites (Table 1). The dominant species in both GTR's was overcup oak, whereas it ranked fourth in the control site. Mean dbh of overcup oak in the GTR's (GTR 1, $\bar{x} = 47.5$ cm, SE = 3.7, $n = 31$; GTR 2, $\bar{x} = 48.8$ cm, SE = 3.9, $n = 23$) was larger ($P = 0.018$) than in the control site ($\bar{x} = 32.9$ cm, SE = 3.8, $n = 19$). Willow oak (*Quercus phellos*), the dominant species in the control site, ranked fifth in GTR 1 and sixth in GTR 2. Cherrybark oak and American sweetgum (*Liquidambar styraciflua*) ranked either second or third at each site.

Table 1. Importance values for dominant overstory trees in greentree reservoir (GTR) 1, GTR 2, and an adjacent bottomland control at Noxubee National Wildlife Refuge, Mississippi, 1988.

Species	GTR 1	GTR 2	Control
Overcup oak (*Quercus lyrata*)	59	57	27
American sweetgum (*Liquidambar styraciflua*)	47	33	45
Cherrybark oak (*Quercus falcata*)	42	38	49
Red maple (*Acer rubrum*)	41	—[a]	—[a]
Willow oak (*Quercus phellos*)	19	23	65

[a] Denotes absence of a species.

Differences in relative presence of flood-tolerant seedling species were evident among sites. Although overcup oak was a minor component in the control site, it dominated in both GTR's in 1988 and 1989 (Table 2). Willow oak seedlings also are considered flood tolerant (Hall and Smith 1955, Hosner and Boyce 1962), but their presence in the GTR's was similar to the control site in 1988. In 1989, willow oak was not a dominant species in any area. Cherrybark oak was among the dominant species only in GTR 2 in 1988. Relative presence of flood-tolerant green ash (*Fraxinus pennslyvanica*, Hall and Smith 1955, Hosner 1959, Hosner and Boyce 1962) was lower on the GTR's than on the control.

Changes in seedling composition occurred between years in the GTR's. Although the relative contribution of flood-tolerant overcup oak, red maple (*Acer rubrum*), and American hornbeam (*Carpinus caroliniana*) was generally similar between years, presence of other flood-tolerant species in the GTR's increased (Table 2). American silverbell (*Styrax americana*) in GTR 1, waterelm (*Planera aquatica*) in GTR 2, and common buttonbush (*Cephalanthus occidentalis*) in both GTR's increased in relative presence from 1988 to 1989. There was a notable decrease in American elm (*Ulmus americana*) from 1988 to 1989 in the GTR's.

The control site also shifted in seedling composition between years, but species were less flood tolerant. The most prominent shifts were increased relative presence of common pawpaw (*Asimina triloba*) and shagbark hickory (*Carya ovata*) and decreased presence of Nuttall oak (*Quercus nuttallii*). Pawpaw absolute density decreased 17% between years, and shagbark hickory increased 25%. In contrast, Nuttall oak (ranked first in 1988) decreased 90%. Overcup oak (ranked sixth in 1988) and willow oak (ranked fifth in 1988) were not dominant in 1989.

Table 2. Importance values for dominant seedlings in greentree reservoir (GTR) 1, GTR 2, and an adjacent control bottomland site at Noxubee National Wildlife Refuge, Mississippi, 1988 and 1989.[a]

	GTR 1		GTR 2		Control	
Species	1988	1989	1988	1989	1988	1989
Overcup oak (*Quercus lyrata*)	89	83	81	74	9	
Red maple (*Acer rubrum*)	30	28	14	9	23	18
American elm (*Ulmus americana*)	22	8	15	8	17	19
American hornbeam (*Carpinus caroliniana*)	5	7	16	22		
Willow oak (*Quercus phellos*)	8		11		14	
Green ash (*Fraxinus pennsylvanica*)	6				18	25
Nuttall oak (*Quercus nuttallii*)					54	17
Others[b]		23	8	22		23

[a] No entry indicates species not found.

[b] Common buttonbush (*Cephalanthus occidentalis*), American silverbell (*Styrax americana*), and waterelm (*Planera aquatica*) occurred in GTR 1 and 2 in 1989. Cherrybark oak (*Quercus falcata*) occurred in GTR 2 in 1989. Pawpaw (*Asimina triloba*) and shagbark hickory (*Carya ovata*) occurred in the control site in 1989.

American hornbeam, shagbark hickory, possumhaw holly (*Ilex decidua*), and swamp hickory (*Carya leidodermis*) were sapling species common to all sites. American hornbeam ranked first on all sites. Possumhaw holly was the only other species that ranked consistently higher than fourth among areas.

Stand structural characteristics

Number of trees/ha varied among sites. GTR 1 and the control site had similar tree densities, but GTR 2 had approximately 19% fewer trees. Mean dbh did not differ ($P = 0.06$) among sites. Basal areas were 16% and 21% less in GTR's 1 and 2, respectively, than in the control area. Canopy openness was greater ($P = 0.008$) in both GTR's than in the control area. Seven percent of the control site lacked canopy cover compared to a combined average of approximately 12% for the GTR's.

Mean number of saplings/ha was 2 and 3 times greater ($P = 0.001$) in the control site than GTR's 1 and 2, respectively (Table 3). In 1988 and 1989, mean numbers of seedlings/ha were greater ($P = 0.001$) in GTR's 1 and 2, respectively, than in the control site. Seedling density decreased between years ($P = 0.0001$) in all areas. Seedling density decreased 77% in GTR 1, 73% in GTR 2, and 87% in the control site.

In GTR 1, overcup oak accounted for approximately 71% and 66% of seedlings in 1988 and 1989, respectively. It accounted for 62% of seedlings in 1988 and 54% in 1989 in GTR 2. However, overcup oak accounted for only 5% of seedlings in the control site in 1988 and 4% in 1989. Seventy-nine percent of overcup oak seedlings in 1988 and 86% in 1989 occurred on approximately 22% of the land area on GTR 2. Sixty-seven percent of overcup oak seedlings in 1988 and 77% in 1989 occurred on approximately 26% of the land area on GTR 1. These were low sites normally occupied by overcup oak.

Potential explanations

Overstory

Broadfoot (1967) reported that overcup oak exhibited a 20% radial growth increase over unflooded, control trees in a Mississippi stand flooded annually from February–July for 4 years. Fredrickson (1979) concluded that GTR management enhanced overcup oak growth primarily because of increased soil moisture conditions. Additionally, overcup oak survived 4 years of complete inundation (Broadfoot and Williston 1973). Although mean dbh was greater in the GTR's, some larger overcup oaks in each GTR may be residual trees from past harvests. Also, comparative stand data prior to GTR management were unavailable. Therefore, differences may not be entirely due to GTR management.

Willow oak is considered moderately tolerant of flooding (McKnight et al. 1980), and flooded trees have exhibited increased radial growth (Broadfoot 1967). These findings suggest that willow oak may respond to GTR management similar to overcup oak. However, relative density of willow oak in GTR's 1 (5%) and 2 (6%) was less than in the control area (18%). Observations of windthrown willow oak in the GTR's with no apparent symptoms of decreased vigor suggest that windthrow, a common problem in GTR's (Wigley and Filer 1989), was the probable cause for their reduced contribution. Because willow oak and overcup oak occurred on similar sites, continued losses could result in reduced willow oak regeneration and overcup oak dominated sites.

Cherrybark oak is intolerant of flooded or saturated soils persisting longer than a few weeks during the growing season (McKnight et al. 1980). Cherrybark oak flooded in <30 cm of water died after 1 year of inundation (Broadfoot and Williston 1973). In contrast, sweetgum is moderately flood tolerant, capable of surviving several months of flooded or saturated soil during the growing season (McKnight et al. 1980). Increased growth rates have been reported in

Table 3. Mean number (95% CL's, $n = 50$) of saplings and seedlings/ha in greentree reservoir (GTR) 1, GTR 2, and an adjacent bottomland control, Noxubee National Wildlife Refuge, Mississippi, 1988 and 1989.

Variable	Year	GTR 1		GTR 2		Control	
		$\bar{x}$	CL	$\bar{x}$	CL	$\bar{x}$	CL
saplings/ha	1989	1,025 A[a]	989–1,061	726 A	697–755	2,212 B	2,160–2,264
seedlings/ha	1988	35,348 A	33,570–37,172	24,796 A	23,832–25,779	16,511 B	15,714–17,328
	1989	8,149 A	7,606–8,711	6,753 A	6,753–7,187	2,160 B	2,004–2,322

[a] Means followed by unlike letters within rows differ ($P < 0.05$).

sweetgum from flooding or irrigation (Broadfoot 1964, 1967). Despite differences in their abilities to tolerate flood conditions, no distinct difference in the relative presence of either cherrybark oak or sweetgum was apparent among sites.

Seedlings

Evaluating effects of winter drawdown and 2-year flooding cycle was confounded by the 1989 spring and summer flooding. Repeated stem die back was evident on all red oak seedlings during 1989 growing-season flooding. Cherrybark oak seedlings likely were adversely affected by extended winter flooding, although the extensive flooding immediately after 1989 drawdown prevented an assessment. However, cherrybark oak regeneration during 1988 in GTR 2 may have benefitted from winter flooding and subsequent increased early-spring soil moisture. Spring rainfall in 1988 was only 55% of the 30-year average.

Despite similar flood tolerance, overcup oak, green ash, and willow oak seedlings in the GTR's had different relative presence. Overcup oak increased because its seedlings and seeds were more tolerant of saturated soil conditions. However, stem dieback from previous years was evident on overcup oak seedlings, indicating repeated flood stress to this flood tolerant species. Decreased relative contribution of green ash in GTR's probably reflected poor seed viability or premature germination of seed immersed in water or both. The GTR's were flooded in November, which produced conditions not conducive for green ash regeneration (DuBarry 1963, Malecki et al. 1983). Despite the reduction in overstory willow oak in the GTR's, the relative presence of willow oak seedlings was similar to that in the control area in 1988. Because willow oak occurs with overcup oak in these minor stream bottoms, continued loss of willow oak trees will result in domination by overcup oak regeneration.

Shifts in species composition in the GTR's between years may be related to extensive flooding in spring and summer of 1989. Thus, shifts in species may not have been directly caused by GTR winter management. However, the GTR levees impounded overflow from Noxubee River to a depth at least equal to the depth associated with normal GTR winter management. The levee systems contributed to a greater extent and period of flooding, particularly in areas not normally flooded extensively. The shift in seedling composition in the GTR's toward flood-tolerant species may reflect an interaction among these factors.

Growing-season flooding influenced seedling density. Although overcup oak had the greatest seedling density and dominated seedling regeneration in both GTR's, it was confined to approximately 25% of the land area. These areas were poorly-drained sites on which overcup oak normally would occur under natural flooding regimes.

The shift in species composition on the control site was the result of differential density changes among species based on topographic position. The poorly-drained sites in the control area were affected more severely by extensive 1989 flooding (i.e., greater frequency and duration of flooding) than better-drained sites. Shagbark hickory and pawpaw occurred on better drained sites that were flooded less frequently and for a shorter duration. These 2 species had low or no density changes. In contrast, more flood-tolerant species had large density decreases, which caused less flood-tolerant species to increase their relative ranking. Shifts in species composition on the control site agreed with current silvicultural understanding of the interaction between floodwater and topographic position and its ultimate influence on species composition (Hodges and Switzer 1979).

Saplings

Consistency in relative rankings of dominant sapling species among sites suggested that saplings were less influenced by the modified flooding regime or growing-season flooding than either overstory or seedling composition. This hypothesis was supported by the high relative rankings of flood-intolerant shagbark hickory in the GTR's. The absence of sapling-sized overcup oak in the GTR's, despite overcup oak being flood tolerant and the dominant seedling, indicated a lack of seedling development into the sapling stage.

Although the control site and GTR's had similar sapling species composition, sapling density was considerably less in the GTR's. This result suggested sapling mortality in all species may have occurred in the low elevation end of the GTR because of longer periods of flooding and saturated soil conditions.

GTR water management may be arresting sapling development. Reduction in sapling density and in overstory basal area increased canopy openness in the GTR's. Increased sunlight should have benefitted red oak regeneration in the GTR's; however, we found no sapling-sized red oaks.

Management recommendations

There was no indication that overcup oak regeneration dominated red oak sites. Therefore, oak regeneration within GTR's should be evaluated on site-species relationships rather than on composite seedling values. Growing-season flood control and efficient floodwater discharge seems critical to seedling development and should be integrated into GTR management.

Inclusion of red oaks in future stand composition requires establishing red oak seedlings and allowing them to develop into advanced regeneration of adequate size. Sapling heights ≥1.4 m are needed if trees are to develop into codominant and dominant positions in the future stand (Sander 1972, Loftis 1982, Hodges and Janzen 1986). Also, sufficient height is required to protect regeneration against periodic overflow during the growing season (McDermott 1954). Because water management may be arresting sapling development, a 2-year flooding cycle may be too short for adequate red oak regeneration to develop. Based on red oak growth rates (Hodges and Janzen 1986, Sander 1972), an establishment period of 4 years without flooding, depending on the extent of unscheduled flooding, may be necessary to ensure required seedling development. Regeneration should be monitored closely.

The Noxubee River periodically overflows during the growing season. Between March and September 1989, both GTR's were inundated 5 times, with inundation lasting approximately 2 days longer in the GTR's than in the control site. The importance of the river's overflow on the overstory component was not assessed, but duration, timing, and frequency of episodic, growing-season flooding should be evaluated.

Data were insufficient to evaluate effects of the 2-year flooding cycle on overstory species. Windthrown willow oak losses probably were related to increased soil-water saturation. A 2-year flooding cycle should improve soil aeration and decrease windthrow. However, benefits to tree vigor may be negated if water drawdown begins after initiation of tree growth. Accordingly, shorter duration winter flooding to allow adequate drainage before annual tree growth begins should be considered. This strategy should benefit long-term tree vigor, seedling establishment, and sapling development. Ideally, timing of water drawdown should be based on phenology of desirable species. Importantly, there was no indication of decreased vigor in willow oak based on crown condition. Therefore, routine and systematic monitoring programs for desirable species should be a part of GTR management.

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