Grass Carp in Guntersville Reservoir: A Review of Fisheries Impact Assessments

by

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Field evaluation of the impact of grass carp on the fish fauna in Guntersville Reservoir in Alabama now spans more than a decade. Assessments began with the trial release of 4,500 monosex fish in a 160-ha embayment and are continuing with the introduction of 100,000 triploid fish in 1990 in the open reservoir, a 27,500-ha impoundment of the Tennessee River. The initial phase (1983-1988) was oriented more to the total fish community (Tennessee Valley Authority (TVA) 1987, 1989), while the current emphasis has been on the sport fishery. However, standing stock estimates of largemouth bass from the first phase served as an important reference. The largemouth bass fishery in this eutrophic reservoir is generally considered outstanding, with the weight of the catch for a 3-day tournament (300 to 400 anglers) often exceeding 3,000 kg. A substantial fishery also exists for the following: bluegill and redear sunfish, black and white crappie, white bass, blue and channel catfish, and sauger. In this review, some of the key results to date are discussed relative to determining or predicting an impact of grass carp on the sport fishery in Guntersville Reservoir.

Bain (1993) has provided an independent perspective on the utilization of grass carp in this reservoir, leading up to the 1990 stocking. He used Guntersville as a case study in developing a checklist for assessing impacts of introduced species, particularly grass carp in large systems. The list was grouped into six categories: population control, hybridization, diseases and parasites, habitat alterations, biological effects, and management issues. Following his protocol, results in this review primarily address potential impacts related to population control (grass carp reproduction and recruitment) and management issues (sport fishery).

Also, the TVA assessment of grass carp in this reservoir was incorporated into the Joint Agency Guntersville Project (JAGP) in 1990. This 5-year demonstration, sponsored by TVA and the U.S. Army Corps of Engineers (USACE), was established to assess a broad array of issues pertaining to aquatic plant management, including the effectiveness and impact of various plant control methods in addition to grass carp. In this context, we judged that the common variable or agent for potential fisheries impacts is the reduction of aquatic plant biomass or areal coverage. The effects of changes in areal surface coverage, expressed as a percentage of total reservoir area, are examined here.

Stocking Rate and Aquatic Plant Conditions

Between late April and mid-July in 1990, a total of 100,000 grass carp were stocked at 23 locations in the lower two-thirds of Guntersville Reservoir. The objective was to stock grass carp at a low-to-intermediate rate to substantially reduce hydrilla and obtain only limited control of other taxa, particularly Eurasian watermilfoil (TVA 1990). As this plan was developed in 1988, the surface coverage of aquatic macrophytes exceeded 8,000 ha, or about 30 percent of the reservoir. Following approval by the Alabama Game and Fish Department to stock 12 triploid grass carp per vegetated hectare, contracts were initiated in spring 1989 to obtain fish for stocking in

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1990. However, because of a natural decline of vegetation that began in summer 1989, the stocking rate was 17/hectare of vegetation by the time of stocking in 1990. The actual density of grass carp in Guntersville Reservoir was further confounded by the legal release of about 20,000 grass carp during 1987-1989 by private citizens or lake user groups. Under these circumstances, however, the estimated density of grass carp following stocking in 1990 did not exceed 20 per vegetated hectare. In comparison, grass carp were stocked at a rate of 47/hectare of vegetation in the trial study, which resulted in no adverse fisheries impacts.

Areal surface coverage of aquatic vegetation was determined from an aerial photographic survey conducted each September. As indicated, aquatic macrophytes in this reservoir were apparently undergoing a natural decline as the grass carp were introduced. However, for additional analysis of this issue and a more complete description of aquatic plant conditions related to grass carp in Guntersville Reservoir (see Webb et al., this volume). As a reference for this fisheries review, the levels of percent coverage since 1988 were as follows:

1988	1989	1990	1991	1992	1993
29	21	12	8	9	11

This unexpected and rapid decline in plant coverage compromised fisheries assessments relative to intermediate and high levels of plant coverage, as the original minimum target level was 10 percent.

Population Control

Normally, the use of triploid grass carp would preclude the need for monitoring for reproduction and recruitment (Bain 1993). Also, successful spawning by diploid fish appeared to be a remote possibility, based on the literature and the absence of grass carp larvae in numerous larval fish samples collected in this reservoir for assessing power plant siting and operations. Conditions for grass carp spawning include the following: water temperature, 23 to 28 °C; high turbidity; and sustained flows of 0.6 to 1.8 m/s for a distance of 40 to 50 km (Stanley, Miley, and Sutton 1978). Water temperatures in this range do not occur until late May in this reservoir, when the probability of required flows is greatly diminished, occurring only in a rare flood event. However, given the presence of diploid fish in the reservoir from previous introductions, monitoring for evidence of grass carp reproduction was conducted to allay public concern on this issue and for experimental control.

Because grass carp larvae typically move into vegetated overbank areas a few days after hatching, a sampling regime utilizing light traps was selected as the best monitoring method for early detection. The light traps used were a modification of the quatrefoil-design (Floyd, Courtenary, and Hoyt 1984). Four transects in the middle-to-lower portion of the reservoir were sampled for 6 weeks beginning in June. Seven traps per transect were set after dark and fished for 2 hr. Samples were preserved and processed in the laboratory. Although large numbers of larval and juvenile fish were collected, including several taxa, no grass carp larvae were collected in 1990-1993. Also, no juvenile grass carp were collected in cove rotenone surveys conducted at five sites in mid-July during this time period.

The other issue relative to population control is the dispersal of grass carp from Guntersville Reservoir that could result in concentrations of fish with undesirable effects in other reservoirs upstream or downstream. To date, we have no evidence that this has occurred.

Sport Fishery

A comprehensive sportfishing census or creel survey, based on nonuniform probability sampling, was initiated in February 1990, to estimate total recreational angler effort, fish harvest, catch rate, and trip expenditures (Fisheries Information Management Systems, Auburn, AL). The survey was stratified spatially and temporally. Temporal stratification included 10 monthly blocks (February-November) divided into weekdays (Monday-Thursday) and weekend days (Friday-Sunday). The reservoir area sampled was divided into three strata, each approximately 8,000 ha, designated as lower, middle, and upper reservoir. Sampling effort for each of two roving clerks was 20 days per month.

Total angler effort (nontournament fishing) was highest in 1990, 1.6 million hr, but declined 63 percent by 1993. The decline in fishing effort occurred among both boat and bank anglers (Figure 1). Likewise, total number of fish caught peaked in 1990, >2 million, and declined 70 percent by 1993. Except for largemouth bass, catch rates remained stable or increased (Figure 2). Angler effort and total catch were consistent among strata over time: highest values in the lower zone (A), followed by the middle (B), and then the upper zone (C). However, the levels of plant coverage in these three zones were just the opposite: 24 to 30 percent (C), 6 to 9 percent (B), and 0.2 to 4 percent (A). More than 90 percent of the effort was by Alabama resident anglers, with an equal percentage of anglers traveling less than 160 km. Economic value, based on trip expenditures plus the willingness-to-pay value, ranged from $4.15 million in 1990 to $1.65 million in 1993, although the hourly rate was higher in 1993 ($2.75/hr) than in 1990 ($2.57/hr). Trip expenditures alone declined $1.4 million during this period, with the largest decline ($0.8 million) occurring between 1992 and 1993.

Targeted angling effort for largemouth bass comprised two-thirds of the total angler effort in this reservoir throughout 1990 to 1993 (Figure 3). Approaching 1.0 million hr in 1990, it declined 58 percent by 1993. Catch rate (release and harvest) ranged from 0.66/hr in 1990 to 0.44/hr in 1993, which was a slight increase to 1992. Biomass harvested (removed from the reservoir) was 145,000 kg in 1990, but it declined more than 80 percent by 1993 because of the reduction in effort and a 66-percent decrease in the harvest rate of bass. However, mean weight of bass harvested

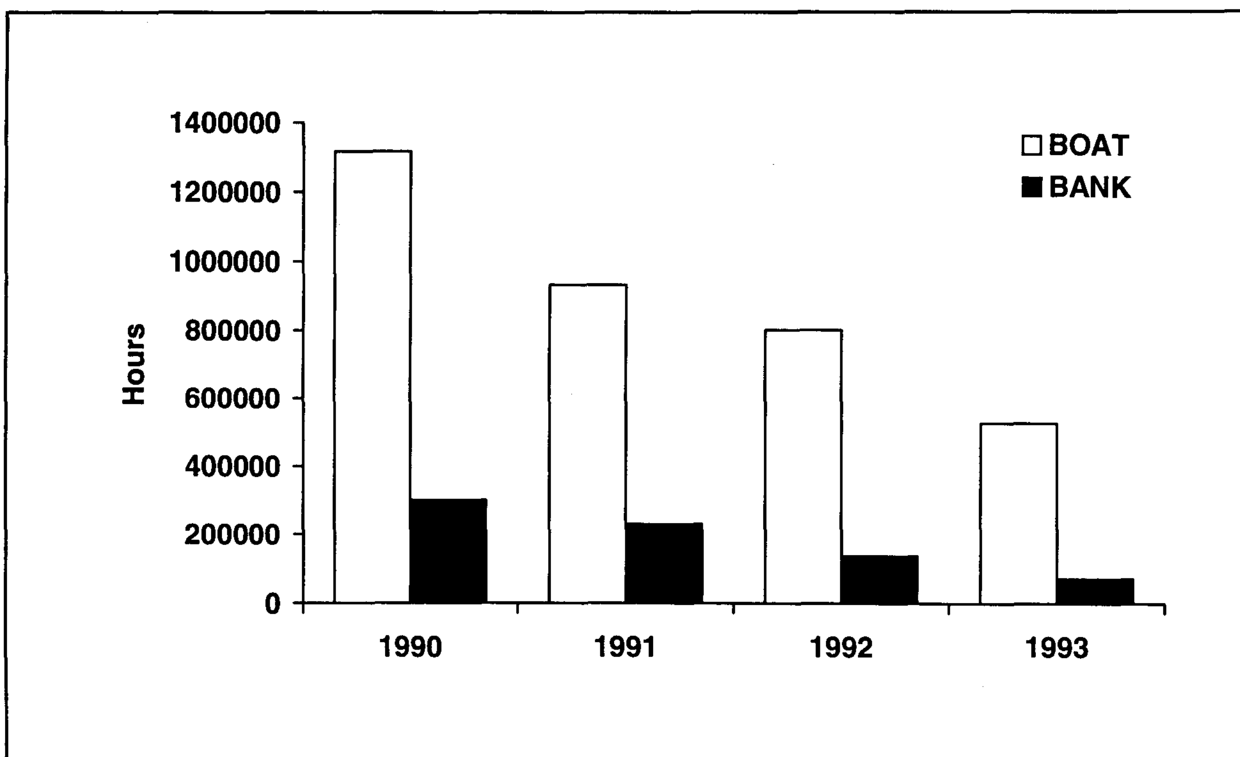

Figure 1. Total effort (hours) of boat and bank anglers during 1990-1993, Guntersville Reservoir

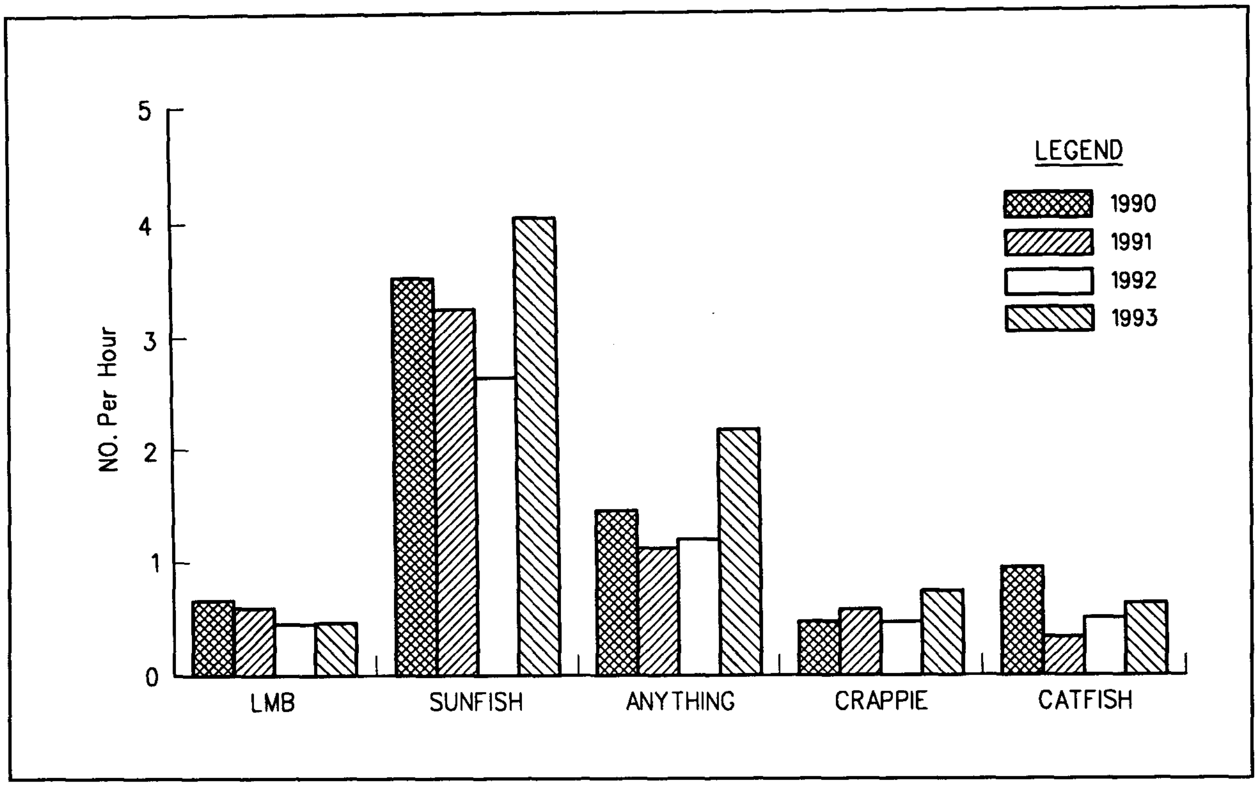

Figure 2. Catch rate (release and harvest) of five categories of sportfish during 1990-1993, Guntersville Reservoir (LMB–Largemouth Bass)

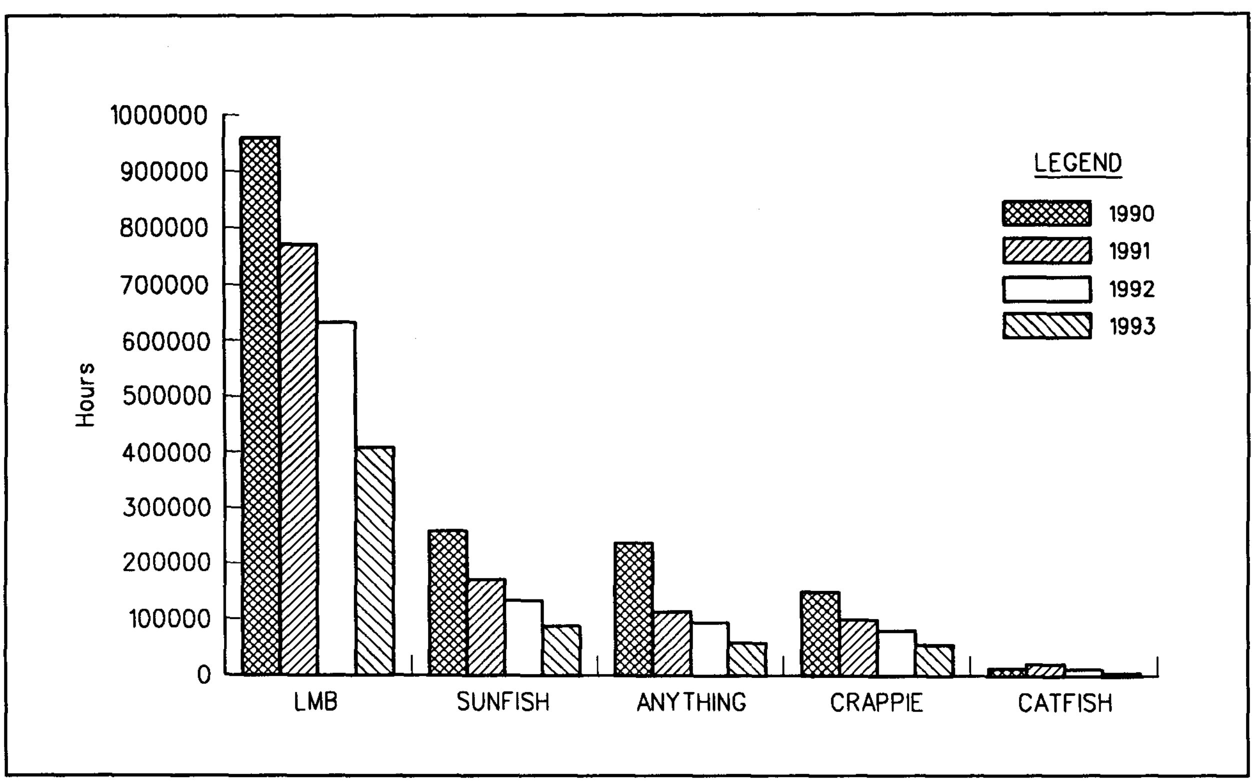

Figure 3. Angler effort (hours) expended for five categories of sportfish during 1990-1993, Guntersville Reservoir (LMB–Largemouth Bass)

was higher in 1993 (0.79 kg) than in 1990 (0.62 kg). The release rate of bass was relatively stable, 0.48/hr in 1990 to 0.38/hr in 1993, while the harvest rate declined from 0.18/hr to 0.06/hr. Partly because of the large numbers of bass harvested in 1990-1991, variable year-class production, and faster growth rates, a 381-mm minimum length limit was imposed on this reservoir in October 1993. Prior to this, there was no length limit; so the release rate was voluntary.

Largemouth Bass Population Status

To determine the standing stock and relative abundance of largemouth bass in Guntersville Reservoir, cove rotenone surveys and electrofishing were selected initially as reliable methods to monitor the bass population as well as various other species in the fish community. Rotenone samples were collected at five coves (1.2 ha) in mid-July in 1990-1993, and electrofishing samples (10 timed-runs) at nine stations were collected in September-October. Although autumn electrofishing was considered to provide a consistent estimate of relative abundance and an adequate sample of bass to examine size structure of the population, density and biomass estimates of harvestable-size (>250-mm total length (TL)) largemouth bass from standard 1.2-ha rotenone surveys were questionable. Results of the creel survey in 1990-1991 showed a mean harvest rate for bass of 5.2 kg/ha, whereas the mean standing biomass estimate for this period was 6.8 kg/ha, suggesting that fishing mortality was extremely high or the biomass estimate was low. Based on the continuing high catch rate in the creel census and limited spring electrofishing samples, it appeared to be the latter. In spring 1992, an electrofishing catch-depletion technique was evaluated (Maceina, Wrenn, and Lowery 1994) and subsequently included in the sampling regime for spring 1993 and 1994. Basically, this entailed block-netting seven coves (total area 21.5 ha) and depleting the bass population by multiple electrofishing runs. This provided another estimate of standing biomass and a large sample of bass for size structure and age-growth determinations.

Although comparable creel and electrofishing surveys were not conducted during the 1980s when aquatic plant coverage was the highest, (23 to 29 percent), large scale-rotenone surveys (11 ha) were conducted (1983, 1986, and 1988) within the 160-ha trial embayment in which the level of macrophyte coverage was as high as 75 percent. Biomass estimates of harvestable largemouth bass from these surveys ranged from 36 kg/ha in 1983 to 30 kg/ha in 1988. For comparison, biomass estimates determined by electrofishing catch-depletion in 1993 and 1994 were 33 and 32 kg/ha, respectively (Table 1). The accuracy of both sampling methods (large rotenone and catch-depletion electrofishing) for determining the true population biomass or density of largemouth bass in this reservoir will always be uncertain. However, in our opinion, it is unlikely that actual biomass in the 1980s was significantly higher than the estimates reported here. Under similar conditions (higher water clarity, increasing aquatic macrophytes, and longer water retention time) in 1986 in Kentucky Reservoir (350 km downstream), the standing biomass of largemouth bass was 21 kg/ha (Buynak, McLemore, and Mitchell 1991).

Table 1
Biomass of Harvestable (>250-mm TL) Largemouth Bass and Population Size Structure in Guntersville Reservoir, 1983-1994

Year	Method[1]	Biomass kg/ha	Relative Stock Density[2] PSD (40-70)	RSD-P (10-40)	RSD-M (0-10)
1983	LR	36	40	8	1
1986	LR	31	30	7	0
1988	LR	30	16	7	1
1990	AF	–	48	21	7
1991	AF	–	43	18	4
1992	AF	–	53	25	8
1993	CD	33	63	26	7
1994	CD	32	46	17	5

[1] Sampling method: LR –large rotenone; AF–autumn electrofishing; CD–catch-depletion electrofishing.
[2] Relative Stock Density (Gabelhouse 1984), PSD = 100 (quality-length fish/stock-length fish); RSD-P = percentage of bass >381-mm TL; RSD-M = percentage of bass >508-mm TL.

Both methods did provide large samples of bass for examining population size structure under disparate levels of aquatic plant coverage. Based on Relative Stock Density (RSD) ratios (Gabelhouse 1984), the current size structure of the largemouth bass population in this reservoir is balanced, whereas the structure in the 1980s reflected an imbalance toward smaller fish (<304-mm TL). Accordingly, the RSD-P ratio (percentage of bass with TL equal to or greater than 381 mm) in the 1980s was below the accepted range, 10 to 40 percent (Table 1). The decline in PSD and RSD-P ratios in 1994 occurred primarily because of highly successful recruitment of the 1992 year class to stock-size (203- to 303-mm TL), while growth rates for age-1 and age-2 bass increased from 1993 (exceeding Alabama statewide mean growth rate).

Additional sampling (small-plot rotenone and electrofishing surveys) during 1990-1993 was conducted specifically to assess reproductive success and early recruitment of largemouth bass (Maceina, Rider, and Lowery 1993). Given the large numbers of young bass that are commonly found in aquatic plant colonies in this reservoir and in other water bodies (Durocher, Provine, and Kraai 1984; Moxely and Langford 1985), we assumed a strong link between aquatic plant abundance and recruitment of age-1 bass to the population. However, as noted in the following summary, this was not necessarily a valid assumption.

From 1990 to 1993, age-0 largemouth density in August was higher in submersed vegetation than unvegetated areas for 3 of these 4 years (Table 2). However, even though age-0 abundance of bass was generally greater in vegetated regions in late summer, electrofishing catch rates of these fish at age-1 indicated abundance in upstream vegetated areas was higher for only one of these 4-year classes produced between 1990 and 1993. In fact, abundance of age-1 bass from the 1992 year class produced in vegetation was less than that estimated in unvegetated regions in June 1993 (Table 2). This occurred even though density was about nine times more abundant in vegetation when estimated in August 1992 when these fish were age-0.

Table 2
Density and Relative Abundance of Age-0 and Age-1 Largemouth Bass in Guntersville Reservoir, 1990-1993

Year Class	Collection Time	Variable	Habitat: Plant	Habitat: No Plants
1990	Aug 90	N/hectare	48	71
	Nov 91	N/hour	16	20
1991	Aug 91	N/hectare	387	22*
	Apr 92	N/hour	14	6*
1992	Aug 92	N/hectare	883	104*
	Mar 93	N/hour	9	8
	Jun 93	N/hour	14	31*
1993	Aug 93	N/hectare	366	104*
	Mar 94	N/hour	28	38

Note: *Significant ($P < 0.05$) difference between values in rows.

Young largemouth bass inhabiting aquatic vegetation in Guntersville Reservoir usually grew slower than those fish collected from unvegetated areas (Table 3). Size differences between vegetated and unvegetated habitats were not due to differences in spawning time as indicated by daily growth rings. Back-calculated growth rates of young largemouth bass as young as 30 days old were less in vegetated than in unvegetated areas, and by August, daily growth rates were about 10 to 20 percent faster in unvegetated habitats. Slower growth conferred smaller size by the fall of each year, and size-dependent mortality likely caused a reduction of reproductive success by age-1 and contradicted what seemed apparent by age-0. Even though greater size-dependent mortality was evident for young bass inhabiting vegetated areas, size at age-1 was generally less than observed for fish inhabiting unvegetated regions (Table 3).

Trophic production (directly or indirectly via algal biomass or zooplankton) did not appear related to differences in age-0 bass density and growth. In spring-early summer 1991, 1992, and 1993, crustacean macrozooplankton densities were either similar or higher in unvegetated than in vegetated habitats. Thus, aquatic vegetation provided habitat and environmental conditions conducive to high abundance of age-0 bass. Likely, mechanisms for greater age-0 abundance in vegetation included a reduction in predation, given that

Table 3
Mean Total Length (mm) of Age-0 and Age-1 Largemouth Bass in Guntersville Reservoir, 1990-1993

Year Class	Collection Time	Habitat: Plant	Habitat: No Plants
1990	Aug 90	83	98*
	Nov 91	244	236
1991	Aug 91	70	92*
	Nov 91	123	145*
	Apr 92	150	151
	Aug 92	196	229*
1992	Aug 92	64	72*
	Oct 92	74	132*
	Mar 93	144	183*
	Jun 93	185	184
1993	Aug 93	69	97*
	Oct 93	137	142
	Mar 94	176	203*

Note: *Significant ($P < 0.05$) difference between values in rows.

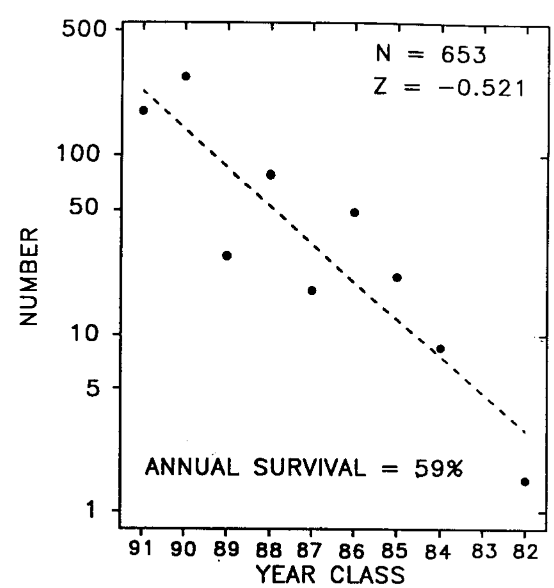

Figure 4. Number of age-2 (1991 year-class) to age-11 (1982 year-class) largemouth bass plotted against year class. Z represents the slope coefficient of the regression (dashed line) and is the instantaneous mortality rate

plants provided refuge from predation, and dense populations of macroinvertebrates, other than macrozooplankton, provided food (Watkins, Shireman, and Haller 1983; Schramm and Jirka 1989).

Catch-curve analyses (Ricker 1975) of fish age-2 and older conducted in 1993 show alternating year-class strength in this reservoir (Figure 4). Variable year-class strength was not related to plant coverage, but to retention time in April, which coincided with the initiation of largemouth bass spawning. For example, strong year classes were produced in 1986, 1988, and 1990 when late summer plant coverage was 24, 29, and 12 percent, respectively. However, weak year classes were produced in 1987, 1989, and 1991 when plant coverage was high at 23 and 21 percent, but then declined to 8 percent in 1991. The strong year classes of 1986, 1988, and 1990 were associated with April retention times 68, 43, and 25 days, while April retention times for the weak year classes of 1987, 1989, and 1991 were 18, 17, and 11 days, respectively.

Thus, when other environmental conditions are favorable, high levels of aquatic plants may not greatly enhance largemouth bass recruitment in this reservoir. However, when reproductive success is low in unvegetated habitats, aquatic plants appeared in some instances to augment overall recruitment to the population. This occurred in 1991 when age-0 bass density was 18 times less in unvegetated areas and catch rates of this year class at age-1 were twice as high in vegetation the following spring. In support of this, age-2 fish from the 1991 year class collected in 1993 were 30 percent more abundant in upstream vegetated than in downstream unvegetated habitats.

Conclusions

Based on the results examined through 1993, the impact of grass carp on game fish populations in Guntersville Reservoir has been minimal. The status of the largemouth bass population, which receives two-thirds of the total fishing pressure, is good to excellent. Size structure of the population is balanced, current growth rates are high, and the standing biomass is substantial. All of the above are important, particularly in relation to the current fisheries management objectives for this reservoir, which include a 381-mm minimum length limit. In fact, one point of concern is the stocking-piling of fish below the legal limit. This condition can be accelerated or compounded by depressed growth rates of younger bass (<age-4). Negative effects of bass density and excessive aquatic plant structure can, in turn or combination, reduce growth rates substantially. This phenomenon has been demonstrated in this reservoir and in other studies (Colle and Shireman 1980; Bettoli et al. 1992).

Although the presence of grass carp or the reduction of plant coverage has had little or no impact on game/fish populations, these factors appeared to impact on the quality of the sport fishery and the level of angler effort in this reservoir. Both of these parameters, to a great extent, are determined by the angling public. Also, the interaction of quality and level of effort cannot be discounted. Considered separately, the 63-percent decline in total angler effort since 1990 is definitely an area of concern because of the probable decline in revenue to the local economy and possible impact on fishing license sales. We did not analyze or determine the multiple variables that can affect angler effort or the definition of quality. However, for the purpose of this discussion, the following conditions could be considered. For anglers that routinely catch bass at a rate of 0.66/hr, the current (1993) catch rate of 0.44/hr would be a decline in quality. However, catch rates from other established largemouth bass fisheries in various lakes or reservoirs throughout the southeastern United States seldom exceeds 0.3 bass/hr (Van Horn and Birchfield 1981; Farman, Nielsen, and Norman 1982; Chapman and Fish 1983; and Dolman 1991). Because total angler effort at a given site is ultimately determined by where the individual angler decides to fish, the key issue may be how this decision was reached. Was it based on first-hand experience or second-hand information? In contrast, some anglers that fish regularly in Guntersville Reservoir probably consider the decline in fishing pressure as a benefit.

Frequently, the underlying issue in angler opposition to aquatic plant control or management is the amount of surface coverage of aquatic plants. Presumably, there is an optimum level of coverage, but this level probably varies widely depending upon the type of water body. Also, any systematic determination of optimum plant coverage in mainstream impoundments of large rivers, such as the Tennessee, is usually confounded by dynamic changes in water discharge and quality that can affect both plants and fish. Likewise, an optimum level of aquatic macrophytes for the fish community in Guntersville was not determined in the present evaluation, given the narrow range of plant coverage during 1990-1993 and the unexpected and rapid decline in plant coverage as grass carp were being stocked. Based on the current stable condition of the largemouth bass population, recent observations by Canfield and Hoyer (1992) in Florida may be applicable to Guntersville Reservoir. They suggested that when considering the total fish population (community), a moderate macrophyte coverage of 15 percent seems to preclude the probability of any adverse fisheries problems. However, from this survey of 60 lakes, they also found no relation between the standing crop of harvestable largemouth bass and the percent area covered by aquatic macrophytes.

Although the joint agency study (JAGP) officially concludes at the end of 1994, fisheries and aquatic macrophyte assessments will likely be continued at some level, given the major sport fishery in Guntersville Reservoir, other multiple-use conflicts, and the controversy surrounding the use of grass carp.

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