Age and Growth of Grass Carp in Lake Guntersville, Alabama

James V. Morrow, Jr., *U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180*

James P. Kirk, *U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180*

Abstract: A total of 139 grass carp (*Ctenopharyngodon idella*) of unknown ploidy were collected by bowfishing during 1993 and 1994 in Lake Guntersville, Alabama. Ages were determined from sectioned otoliths (lapilli), then age-specific total lengths were back-calculated using scales of known age. Mean back-calculated total lengths of grass carp were 334, 627, 768, 852, 896, 895, 920, 965, and 973 mm at ages 1 through 9, respectively. A length-to-weight relationship was calculated as: weight (g) = 0.00000519 x total length $mm^{3.14}$, $r^2 = 0.92$. A von Bertalanffy growth equation described growth as: $L_t = 954\ (1-e^{-0.590(t-0.257)})$, $r^2 = 0.99$. Growth averaged 2.33 kg/year through age 4; subsequent growth was much slower, averaging 0.71 kg/year. Growth in Lake Guntersville was slower and more variable than in the Santee Cooper reservoirs, South Carolina. Occurrence of 3 age classes not stocked by Tennessee Valley Authority (TVA) precluded mortality estimates.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 49:187–194

Grass carp were first introduced into the United States in 1963 (Guillory and Gasaway 1978) for controlling nuisance aquatic vegetation in both large and small impoundments (Shireman and Maceina 1981, Sutton and Vandiver 1986, Clugston and Shireman 1987). Triploid grass carp were thought a promising development because they are sterile and have consumption habits similar to diploids (Wattendorf and Anderson 1984, Sutton 1985, Wiley and Wike 1986, Allen and Wattendorf 1987). Despite these attributes, use of triploid grass carp for control of aquatic vegetation is still controversial. Concerns include destruction of fish and waterfowl habitat, alteration of fish community structure, and migration out of the target area (Ware and Gasaway 1976, Fedorenko and Frazer 1978, Bain 1993). An additional problem is determining and achieving the desired degree of aquatic vegetation control (Sutton 1977, Leslie et al. 1987, Santha et al. 1991). For example, the complete elimination of all aquatic vegetation such as in Lake Conroe, Texas (Bettoli et al. 1993), or generally unsuccessful use of triploid grass carp in South Carolina farm ponds (Kirk 1992), demonstrates the need for reliable stocking models. Among the parameters needed in such models are growth and density estimates (Miller and Decell 1984).

Lake Guntersville, Alabama, is a 27,500-ha reservoir operated by TVA on the Tennessee River in northeastern Alabama and southeastern Tennessee. This reservoir has a history of infestation by submersed aquatic vegetation which peaked to almost 8,000 ha in 1988 (Webb 1993). Eurasian watermilfoil (*Myriophyllum spicatum*) is the major submersed aquatic plant, although hydrilla (*Hydrilla verticillata*) became well established in the mid 1980s reaching a maximum coverage of approximately 1,200 ha in 1988. As a control measure, TVA stocked 14,200, 4,200, and 100,000 triploid grass carp in 1988, 1989, and 1990, respectively (D. H. Webb, pers. commun.) and individuals and private organizations have stocked unknown numbers of both diploid and triploid grass carp (Bain 1993). Coverage of hydrilla declined to approximately 120 ha by 1991 (Webb 1993).

This paper summarizes collection, aging, and growth of grass carp in Lake Guntersville to support a stocking model developed at U.S. Army Engineer Waterways Experiment Station (Miller and Decell 1984).

Support for this study was provided by the Aquatic Plant Control Research Program managed by J. Lewis Decell. We thank Keith B. Floyd of the Alabama Department of Conservation and Natural Resources and Gary D. Jenkins of TVA for their assistance in collecting grass carp in April 1993. H. Douglas Murphy, Jr. and David G. Brewster from TVA's Murphy Hill laboratory managed collection efforts in 1994 and without their help this paper would not have been possible. Reviews by Richard L. Kasul and C. Thomas Swor markedly improved this manuscript.

Methods

Grass carp collected in bowfishing tournaments and by TVA biologists bowfishing under contract were used in this study. Tournaments were held the nights of 4 April 1993 and 10 April 1994. TVA biologists collected grass carp between 2 June 1994 and 29 September 1994. Gears used by tournament bowfishers varied, but generally consisted of boats modified by addition of lights powered with gasoline generators, recurve bows equipped with heavy spin cast reels, and solid fiberglass arrows. Grass carp were only one of many nongame species targeted by tournament bowfishers. TVA biologists used a specially equipped airboat and specifically targeted grass carp. Archery tackle was similar to that used by tournament bowfishers.

After capture grass carp were measured for total length to the nearest mm and weighed to the nearest 10 grams. Heads were removed and frozen until utricular otoliths (lapilli) could be excised and prepared as described by Victor and Brothers (1982) and Secor et al. (1992). Scales were removed from the area just behind the pectoral fins, approximately on the lateral line. Otolith sections were examined using a Nikon binocular microscope at 40X and 100X magnification. Each otolith was aged twice and discrepancies were resolved by agreement of the authors.

Scales from grass carp, previously aged using sectioned otoliths (lapilli), were placed in a Ken-O-Vision microfiche projector and examined at 12X magnification. Distances from the focus to each annulus and to the margin of the projected image were measured using a Graph Bar sonic digitizer and an IBM personal computer. Lengths at age were back-calculated using the Fraser Lee method (Carlander 1982) with a correction factor calculated by regressing total fish length against distance to scale margin. Scales taken from grass carp at time of stocking were included in this regression.

A length-to-weight relationship was developed for estimating weights from back-calculated lengths. The length-to-weight relationship was computed using a power function (Ricker 1975): weight = intercept x total length^{slope}. The relationship was determined by regressing the log (base 10) of the weight as the dependent variable against the log (base 10) of the length as the independent variable. Thirty-three smaller fish (approximately 200–400 mm total length), accurately measured as they were stocked by vendors in the Santee Cooper reservoirs, were included to improve the length-to-weight relationship. Inclusion of these fish allowed the authors to estimate weights for back-calculated lengths at ages 1, 2, and 3, since no fish of those ages were collected in this study.

A von Bertalanffy growth equation was used to describe growth of Lake Guntersville grass carp (von Bertalanffy 1938). We used nonlinear least squares procedures employing the Marquardt algorithm in FISHPARM software produced by the American Fisheries Society, Computer Users Section.

Results

Seventy-six grass carp were collected in bowfishing tournaments and 68 were collected by TVA biologists. Otolith removal and mounting were successful for 139 grass carp. Both lapilli of 5 grass carp were either lost or destroyed during removal and mounting processes.

Annuli were recognizable in sectioned otoliths. Ages agreed 90% of the time between 2 readings and the authors reached agreement for the remaining 10%. The first 2 annuli on scales were readily identifiable. After age 2, increase in distance to subsequent annuli was small enough that annuli became bunched near the margin and difficult to recognize. Knowledge of otolith age made recognizing scale annuli easier.

Back-calculated length at first annulus was 334 mm (Table 1), slightly larger than stocking size, indicating the first annulus formed during the first growing season in the reservoir. Grass carp grew rapidly from ages 1 through 4, averaging 140 mm/year, but slowed dramatically, averaging only 22 mm/year, after age 4 (Table 1). Growth in length became quite variable after age 5 (Table 1). Rosa Lee's phenomenon (Ricker 1969) was not detected in these fish as very little

Table 1. Mean back-calculated total lengths and estimated weights of 139 grass carp collected in Lake Guntersville, Alabama during 1993 and 1994. Weights were estimated using the formula, Weight (g) = 0.00000519 × mean back-calculated total length$^{3.14}$.

Age	Mean back-calculated length (mm)	SE	Weight (kg)
1	334	5	0.44
2	627	8	3.15
3	768	8	5.96
4	852	10	8.26
5	896	13	9.67
6	895	46	9.64
7	920	32	10.51
8	965		12.21
9	973		12.53

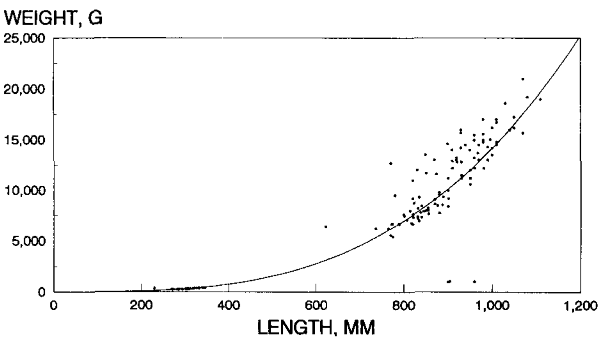

Figure 1. Length-to-weight relationship for 139 grass carp of unknown ploidy collected by bowfishing during 1993 and 1994 in Lake Guntersville, Alabama, and for 33 triploid grass carp measured at time of stocking.

difference was noted between back-calculated lengths from different year classes.

Age-specific weights ranged from 0.44 kg to 12.53 kg for ages 1 through 9, respectively. Growth in weight was rapid through age 4, averaging 2.33 kg/year, but decreased rapidly and varied widely in ages 5 through 9 (Table 1).

The length-to-weight equation was: weight (g) = 0.00000519 x total length mm$^{3.14}$, $r^2 = 0.92$ (Fig. 1). Growth described by a von Bertalanffy growth equation was: $\text{length}_t = 954\ (1-e^{-0.590\ (t-0.257)})$, $r^2 = 0.99$.

Discussion

Traditional collection techniques have been found ineffective for grass carp in large water bodies (Kirk et al. 1992, Kirk et al. 1993). A total of 144 grass carp were collected by bowfishing in this study, indicating bowfishing was effective in Lake Guntersville. Slightly more than half, 76, were collected as byproducts of 2 bowfishing tournaments. The rest were collected by TVA biologists whose success ranged from 0 to 19 grass carp/night. Grass carp in the Santee Cooper reservoirs, South Carolina, were successfully collected by highly skilled tournament bowfishers working under contract (Kirk et al. 1993). Success in this study indicates bowfishing tournaments and bowfishing by fisheries biologists are both effective techniques for collecting grass carp in large water bodies.

In South Carolina studies, where we were reasonably certain unofficial stocking had not occurred and likelihood of grass carp entering the system was low, we used a catch curve to estimate mortality (J. V. Morrow et al., unpubl. data). In this study we chose not to estimate mortality due to collection of fish ages 4, 8, and 9 which could not be explained by TVA stockings. Collection of these fish suggest either 1) grass carp from unofficial stockings or those that entered Lake Guntersville from other systems were collected, or 2) our aging technique was flawed.

Evidence suggests grass carp other than those stocked by TVA were in the system, and our aging technique is valid. Grass carp are unregulated in Alabama and grass carp stocking by private citizens has been documented in Lake Guntersville (Bain 1993). Ages derived by reading otoliths have been validated for many species including large cyprinids (Victor and Brothers 1982). In on-going South Carolina studies, otoliths agreed well between readings, marginal increment analysis suggests annuli are laid down during May-June, and no fish were collected and aged that could not be explained by official stockings (J. V. Morrow et al., unpubl. data). High agreement between readings, similarity between otoliths in this study and those in Santee Cooper studies, and similarity between our results and TVA stockings (Table 2) suggest examination of sectioned lapilli is a valid aging technique for grass carp in Lake Guntersville.

We recommend determining age by reading sectioned otoliths, then back-calculating lengths using scales. This is somewhat unconventional; however, Schramm and Doerzbacher (1982) used a similar technique by confirming age of crappie using sectioned otoliths then measuring along the long axis of whole otoliths to back-calculate length. We cite differences in growth of scales

Table 2. Number of grass carp of each year class (year stocked) collected in Lake Guntersville, Alabama. Year class assumes age 1 at time of stocking.

N collected	Year class	*N* stocked by TVA
8	1991	0
106	1990	100,000
15	1989	4,200
7	1988	14,200
2	1987	0
1	1986	0

and otoliths to justify this technique. Scales grow only when the fish grows while otoliths continue to grow with age regardless of fish growth (Beamish and McFarlane 1987). Therefore, size of the scale should be proportional to fish length while size of the otolith is more likely to be proportional to age.

Another argument for back-calculating lengths from scales is that otoliths often grow disproportionately with respect to length, width, and thickness, usually becoming thicker in proportion to length and width (Beamish and McFarlane 1987). This phenomenon raises the question of which axis of the otolith to measure for back-calculation. Annuli in otoliths of old fish often show up best in the thickened area (Beamish and McFarlane 1987), while length or width of the otolith may be more proportional to fish length. Annuli in this study were readable only in cross sections of the thickest part of the otolith. It is likely growth in this part of the otolith is not proportional to fish length.

Growth can be affected by such factors as temperature, stocking density, food availability, and food quality (Gasaway 1978, Bonar et al. 1993). In Lake Guntersville, growth averaged 2.33 kg/year for ages 1 through 4 (Table 1). This rate is slightly less than for grass carp in the Santee Cooper reservoirs (Kirk et al. 1994) and the former Soviet Union (Gorbach 1961, cited by Smith and Shireman 1983) and substantially less than was reported in Florida by Shireman et al. (1980). Growth after age 5 in our study averaged only 0.71 kg/year (Table 1). Slower growth of older fish may be normal for grass carp or due to lack of preferred foods. Most fish collected in this study had access to substantial amounts of hydrilla through age 2 or 3. At collection, hydrilla was rare in the system and grass carp were apparently consuming filamentous algae and muskgrass (*Chara zeylandica*) (H. D. Murphy, pers. commun.). In contrast, on-going studies in the Santee Cooper reservoirs, where hydrilla is still expanding, showed weight gain per year to be linear through the oldest year class, age 6 (J. V. Morrow et al., unpubl. data). Slowed growth for older fishes in this study may have caused the von Bertalanffy growth equation to be in error. In this regard, a maximum total length of 954 mm was too short, as fish up to a total length of 1,100 mm were collected (Fig. 1).

Use of grass carp in large reservoirs is controversial because of difficulties in achieving proper densities and because of environmental concerns (Bain 1993). One major shortcoming of this study was our inability to estimate mortality and density of grass carp in Lake Guntersville. While cause of hydrilla decline is speculative, large stands of Eurasian watermilfoil remained in the system. We speculate TVA stocking of grass carp may have played an important role in the reduction of hydrilla.

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