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Problems and Prospects for Grass Carp as a Management Tool

John R. Cassani
Lee County Hyacinth Control District, Post Office Box 60005
Fort Myers, Florida 33906, USA

Abstract.—Grass carp *Ctenopharyngodon idella* have been used extensively for vegetation control in the United States since the early 1970s. Based on a review of the literature, the most common result of stocking grass carp to manage aquatic vegetation is elimination of macrophytes and, subsequently, changes in water quality, primary and secondary productivity, structural habitat complexity, and changes in the fish community. Despite the extensive use of grass carp, the probability of predicting these changes is often low due to differences in such dynamic processes as nutrient loading, macrophyte seasonality, and climate among lakes. Variations in consumption rates and preference for certain plant species can further complicate vegetation management with grass carp, especially where mixed-species communities occur. Use of stocking rates that do not account for these differences are largely responsible for the unpredictable impacts of stocking grass carp. Other factors that contribute to the unpredictability of using grass carp for vegetation control are inconsistent survival rates associated with size at stocking, poor water quality, and variable predation pressure. Stocking rates for macrophyte suppression, rather than elimination, are in the developmental stages and preliminary results indicate potential application. These findings, in conjunction with more sophisticated simulation models, refined removal and containment techniques, and integration with other control methods, will likely improve vegetation management with grass carp in the future. However, resource managers will need to place more value on macrophyte suppression rather than elimination so that the low cost of using grass carp is balanced with potentially long-term impacts.

Grass carp *Ctenopharyngodon idella* were introduced into the United States in 1963 by Auburn University and the U.S. Fish and Wildlife Service (Guillory and Gasaway 1978). The primary intent of this introduction was to assess the potential of grass carp for controlling aquatic plants. The Arkansas Game and Fish Commission was the first agency to use grass carp on an operational basis in 1970 when Lake Greenlee was stocked with 2,100 diploid grass carp (Bailey and Boyd 1972). Grass carp were rapidly spread to other areas of the United States, and by 1972 the fish had been introduced to 40 states (Pflieger 1978). Many of the original stockings in Arkansas were in lakes or reservoirs open to stream systems, and by 1974 there were numerous reports of grass carp captured in the Missouri and Mississippi rivers (Pflieger 1978).

The collection of eggs or larvae documented that grass carp can reproduce in U.S. rivers (Conner et al. 1980; Zimpher et al. 1987; Brown and Coon 1991; Anonymous 1993). However, impacts of these naturally reproducing populations have not been documented.

During the late 1970s, the controversy over natural reproduction of grass carp resulted in the production of an intergeneric triploid hybrid. However, the hybrid did not effectively control aquatic weeds (Osborne 1982). Further refinements of triploid induction techniques led to the development of a nonhybrid triploid grass carp (Malone 1984; Cassani and Caton 1986; Thompson et al. 1987). Functional sterility of the triploid grass carp further liberalized its use (Allen et al. 1986; Van Eenennaam et al. 1990; Sanders et al. 1991). As of 1994, 12 states prohibit grass carp introductions, eight have no restrictions, and the remainder allow some form of application, usually by permit, for triploid grass carp (R. J. Wattendorf, Florida Game and Fresh Water Fish Commission, personal communication).

Management Dilemmas

The relatively low costs of using grass carp for aquatic plant control have made it attractive to many user groups. Chemical control of submersed macrophytes in small ponds is 2.6 to 5.4 times more expensive than the equivalent level of control with grass carp (Shireman et al. 1985). Mechanical control is even more expensive, ranging from 2 to 28 times the cost of using grass carp (Cooke et al. 1993). The temptation to rapidly reduce and often eliminate submersed macrophytes with grass carp is always a factor when evaluating management objectives.

Choosing grass carp as a management tool for economic reasons alone reflects a short-sighted approach to managing aquatic plants. Rapid elimination of submersed macrophytes in single-use systems such as irrigation canals and potable water reservoirs—especially if chemical and mechanical plant control methods are incompatible with water use—is a different situation from large multi-use systems with a sport fishery or other biota dependent on some level of macrophyte abundance.

A review of grass carp impacts indicates that submersed macrophytes are usually eliminated from the target area. Macrophyte eradication can have varying effects, some of which result in undesirable impacts to fish community structure, invertebrate diversity and abundance, waterfowl food sources, and water quality (Gasaway and Drda 1976; Bailey 1978; Leslie et al. 1983; Cassani and Caton 1985; Maceina et al. 1992; Bettoli et al. 1993). Other studies have shown that extremes in macrophyte cover, either from some method of control or lack thereof, can negatively affect sport-fish population size structure and abundance, and that intermediate levels are generally desirable (Colle and Shireman 1980; Savino and Stein 1982; Durocher et al. 1984; Engel 1987).

Lake Conroe, a large Texas reservoir, provides a well-documented example of grass carp eradicating submersed macrophytes and the effects on the sport fishery. Grass carp stocked at 74/ha of vegetation eliminated submersed vegetation, primarily *Hydrilla verticillata*, in 2 years. A 7-year poststocking study revealed increases in mean annual chlorophyll-*a* levels with a concomitant decrease in water transparency; blue-green algal density relative to phytoplankton abundance increased and total zooplankton decreased 1.5 years after macrophyte removal (Maceina et al. 1992). Effects on the fishery in Lake Conroe were also documented over the same 7-year period (Bettoli et al. 1993) (Table 1). Species declining after macrophyte removal included phytophilic *Lepomis* spp. (*L. punctatus*, *L. marginatus*, and *L. gulosus*), bluegill *Lepomis macrochirus*, and brook silverside *Labidesthes sicculus*. The density of threadfin shad *Dorosoma petenense*, a pelagic planktivore, increased dramatically after vegetation removal and may have accounted for subsequent large year-classes of yellow bass *Morone mississippiensis* and white bass *M. chrysops*. Biomass and density of channel catfish *Ictalurus punctatus* also increased. The authors concluded that the sport fishery could not be fully assessed but that a change in the structure of the sport-fish community did occur. The original largemouth bass–crappie–hybrid striped bass fishery was replaced by a channel catfish–white bass–hybrid striped bass–largemouth bass–black crappie fishery after macrophyte removal. Limited creel data indicated a decline in largemouth bass catch rates but an increase in average size.

TABLE 1.—Common and scientific names of fish species (Robins et al. 1991) impacted by stocking grass carp into Lake Conroe, Texas.

Common name	Scientific name
Bluegill	*Lepomis macrochirus*
Brook silverside	*Labidesthes sicculus*
Threadfin shad	*Dorosoma petenense*
Yellow bass	*Morone mississippiensis*
White bass	*Morone chrysops*
Channel catfish	*Ictalurus punctatus*
Largemouth bass	*Micropterus salmoides*
Crappie	*Pomoxis* sp.
Hybrid striped bass	*Morone chrysops* × *M. saxatilis*
Black crappie	*Pomoxis nigromaculatus*

Evaluating the significance of changes to a fishery can be highly subjective and may vary according to the evaluator's concept of a desirable fishery. The importance of submersed vegetation to fish populations and lake systems remains controversial, especially when management priorities are focused on one or two species (e.g., largemouth bass and bluegill). The success or failure of vegetation decline from grass carp is thus measured, in many instances, by the way the target fishery responds.

Macrophyte elimination with grass carp is rarely the intended objective, but there are several reasons why intermediate control is rarely achieved. A primary reason is that each lake system has unique conditions that will affect grass carp stocking rates. When these conditions or variables are not measured or accounted for, it invalidates comparisons of stocking rates among studies. Factors that should be considered include climate, nutrient loading, levels of predation affecting grass carp survival, target plant phenology, and different target weed species that affect the rate of consumption by grass carp. These factors are not routinely assessed, because they are often difficult to measure and are highly dynamic on a temporal basis.

Another reason why intermediate control is rarely achieved is that researchers have not taken a uniform approach to quantifying and evaluating important stocking rate considerations. Use of different sizes of grass carp, which have different survival and plant consumption rates, and noncomparable approaches to quantifying macrophyte abundance weaken attempts to build a knowledge base resulting from repetitive experiences. The end result has been a relatively large amount of information, but little that can be used to determine stocking rates.

It is necessary to contain grass carp in the target area to maintain effective stocking levels. Containment is generally practical and inexpensive in relatively small isolated systems, but difficult in large lakes or impounded rivers. Dams, locks, and spillways may restrict grass carp movement temporarily but periodic floods and sporadic escapement can dilute the original stocking density and potentially impact nontarget areas. In Guntersville Reservoir, a large open mainstream reservoir of the Tennessee River, juvenile triploid grass carp remained close to food sources (*Hydrilla verticillata*). Grass carp dispersion increased as the fish matured, resulting in movement well beyond the target area (Bain et al. 1990).

Of even greater concern is the potential natural reproduction of escaped diploid grass carp and the impact of the resulting population. Confirmed spawning of grass carp in the Trinity River, Texas, may have been the result of grass carp that escaped from Lake Conroe (Anonymous 1993). The value of using a sterile triploid grass carp becomes obvious when containment is a problem. Triploid grass carp are certainly as capable of impacting nontarget areas, but the effects are generally limited to the life of the fish.

A consideration of stocking any cultured fish is the possibility of transferring diseases or parasites to wild stocks. Grass carp carry several diseases and parasites known to be transmissible or potentially transmissible to native North American fishes (Riley 1978; Shireman and Smith 1983). However, limiting the use of grass carp on the premise of controlling the spread of new diseases or parasites is somewhat moot because the fish has already been widely distributed in the United States for over 20 years. In addition, triploid grass carp, all of which are produced in hatcheries where it is advantageous to maintain disease- and parasite-free stock, are the only source of grass carp in almost all states where stocking is permitted. Bain et al. (1990) suggested that native fish in open systems stocked with grass carp should have limited vulnerability to new diseases and parasites because those systems may be interconnected to a wide range of aquatic habitats and pre-existing sources of disease and parasites. However, restricting grass carp from pristine systems and connecting water bodies where endangered native cyprinids or other endangered fish species occur would seem appropriate. Much of the concern about parasite dispersal from grass carp stems from the assumption that the Asian tapeworm *Bothriocephalus opsarichthydis* was first introduced into the United States when grass carp were imported in 1963 (Hoffman and Schubert 1984), and that grass carp will aid dispersal of this parasite.

Management Prospects

Adjusting grass carp stocking rates for the diverse and dynamic set of variables affecting consumption rates and plant phenology is a difficult task. As mentioned earlier, the methodological approach to this problem has not been consistent, resulting in little comparability between studies. However, there has been more emphasis in recent years on refining stocking rates and attempting to avoid eradication of submersed macrophytes (Kirk 1992; Bonar et al. 1993a). Consideration for site- or region-specific variables is increasing, and concentrated research on stocking-rate effects in certain regions will allow resource managers to estimate grass carp stocking rates more accurately. In Illinois, Wiley et al. (1987) developed a model that provides an alternative to a single stocking approach. Here, stocking recommendations are based on a serial stocking approach where grass carp are stocked a second time, usually 5 to 7 years after the initial stocking. Serial stocking allows for more management interaction and flexibility and an overall goal of leaving some residual plant population. The stocking recommendations are further qualified by the type and areal coverage of various plant groups based on their preference by triploid grass carp.

In Washington, Bonar (1990) evaluated stocking rates based on estimates of the quantity (metric tons) of vegetation present. Vegetation was quantified by underwater collection of all plant material within randomly located 0.25 m^2 quadrats and expressed as g/m^2 wet weight. In addition, the rates were adjusted for altitude and associated differences in climate. Research on small warmwater impoundments in southwest Florida using stocking rates of three 25–30-cm-total-length triploid grass carp per metric ton of vegetation (preferred plant species) resulted in macrophyte suppression without eradication up to 5 years after stocking at two sites (Cassani et al., in press) (Figure 1).

Grass carp consumption rates and plant growth are highly dynamic variables and are related to temperature, grass carp size, nutrient loads, and grass carp survival. Computer models may be the best approach to dealing with complex and interactive variables associated with determining grass carp stocking rates. Several models are now available, most of which have been developed for application in certain regions of the United States with similarities in climate or target plants. Models already developed include the AMUR/STOCK model (Boyd and Stewart 1991), the Illinois model

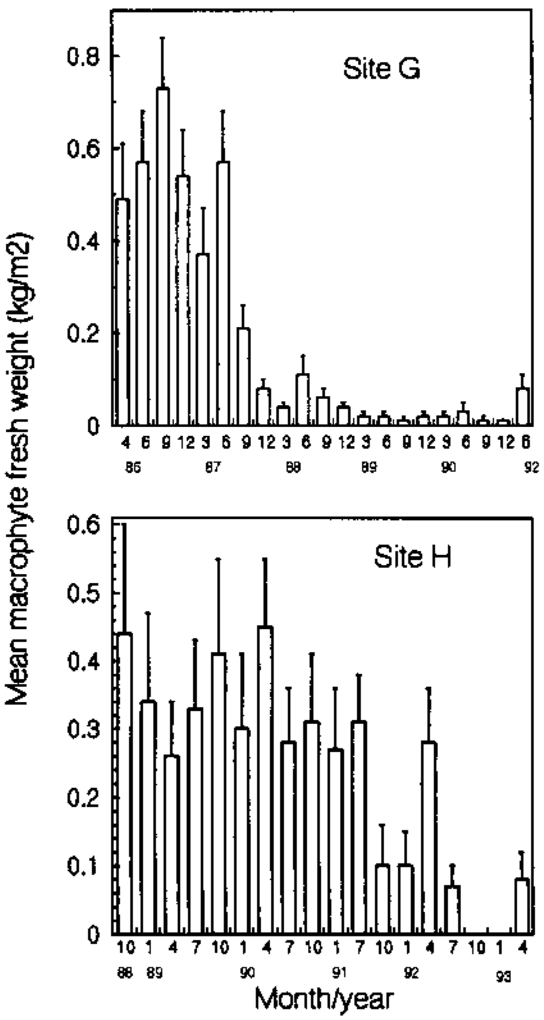

FIGURE 1.—Mean macrophyte density per sampling period at two impoundments in Lee County, Florida, stocked with three 25–30-cm triploid grass carp per metric ton of vegetation. Site G was stocked in July of 1986 and Site H was stocked in January of 1989. Dominant macrophytes at Site G were *Chara* sp. and *Najas guadalupensis*. At Site H the dominant macrophyte was *Najas guadalupensis*. Error bars are 95% confidence intervals. From Cassani et al., in press.

(Wiley et al. 1987), the CONTROL and BIOMASS models developed for areas in Washington by Bonar (1990), and a coldwater model described by Swanson and Bergerson (1988). These tools hold considerable potential for refining and interpreting stocking rates for macrophyte suppression. However, the validity of the simulations is only as accurate as the information supplied. Entering a range of variables (e.g., stocking rates, percent grass carp mortality, etc.) will result in multiple simulations (vegetation decline scenarios), allowing the user to select a stocking rate that will most likely meet the management objective.

Increasingly, stocking grass carp is integrated with other methods of plant control for more precise management, but few if any published studies are available. The value of this approach is that plant density is reduced prior to stocking so that fewer grass carp are used, therefore reducing their impact on water quality and other system components if plant eradication occurs. Also, intentionally understocking grass carp and selectively treating plants with herbicides to maintain desirable levels is an example of the flexibility possible with integrated control. Sutton and Vandiver (1986) found that only 13 triploid grass carp per hectare were able to prevent the regrowth of *Hydrilla verticillata* after initially eliminating it with herbicides, and suggested that three to eight grass carp per hectare may be a low enough rate to allow beneficial macrophytes to reestablish. Costs associated with integrated control will be higher than using grass carp as the only method of control and will have to be prioritized according to the management objectives and anticipated results.

Another approach toward mitigating the long-term effects of overstocking grass carp is to reduce the grass carp population with some type of capture method after the desired level of control has been achieved. Recapture techniques have been evaluated extensively in Florida (Rue Hestand, Florida Game and Fresh Water Fish Commission, personal communication) but nothing has been published to date on the results. The earliest attempts to reduce grass carp populations were with rotenone. Selective removal of grass carp from 80-ha Lake Baldwin (Florida) was attempted by applying rotenone at 0.1 mg/L (Colle et al. 1978). Over half of the grass carp were removed and the authors concluded that this method was practical for obtaining population estimates with potential broader applications.

Bonar et al. (1993b) evaluated seven capture methods in five Washington lakes and concluded that herding was the most efficient method and that it may be effective in small (less than 10 ha), overstocked lakes. Herding involves progressively driving fish with noisemakers (boat motor, plungers, scarelines) from one side of the lake, and preventing their return with a gill net until the entire lake has been traversed. Up to 8.2% of the original population was captured in one lake by herding and seining (Bonar et al. 1993b).

The recent development of a feed pellet containing rotenone has demonstrated relatively good removal rates in small lakes (Rue Hestand, Florida Game and Fresh Water Fish Commission, personal communication). Testing this removal method involved manipulating bait components to increase its palatability to grass carp while reducing its attractiveness to other species. Applications that increased effectiveness of the bait were also refined. Preliminary results indicate that 20–40% of the grass carp in a lake could be removed in a year with this method.

In conclusion, many of the problems associated with the use of grass carp for aquatic weed control have not been adequately addressed. Grass carp are a cost-effective tool for eradicating submersed macrophytes, but their application in large multi-use systems will demand more careful consideration in the future. Progress toward more sophisticated stocking rate models, refined removal and containment techniques, and integration with other plant control methods is slowly taking place and will likely improve the applicability of grass carp for aquatic plant management.

Future research to estimate grass carp stocking rates should address reasons for discrepancies among past studies and avoid inconsistent approaches. The following criteria should be incorporated in new research on grass carp efficacy:

1. stock triploid grass carp that are 250–300 mm total length to minimize predation losses;
2. estimate area of macrophyte cover in hectares and abundance as metric tons wet weight;
3. report stocking rates as number of grass carp per vegetated hectare and number per metric ton of vegetation;
4. determine the lake trophic state as a minimal measure of the system productivity (Carlson 1977; Canfield et al. 1983) that may relate to macrophyte growth potential;
5. stock grass carp during the spring months or before the season of maximum macrophyte growth;
6. assure that transportation and on-site introduction stress are minimized to reduce uncertainties about poststocking survival; and
7. use an appropriate model for developing stocking rates that may more accurately achieve the vegetation management objective.

References

Allen, S. K., Jr., R. G. Thiery, and N. T. Hagstrom. 1986. Cytological evaluation of the likelihood that triploid grass carp will reproduce. Transactions of the American Fisheries Society 115:841–848.

Anonymous. 1993. Confirmed grass carp spawning. Fisheries (Bethesda) 18(3):36.

Bailey, W. M. 1978. A comparison of fish populations before and after extensive grass carp stocking. Transactions of the American Fisheries Society 107:181–206.

Bailey, W. M., and R. L. Boyd. 1972. Some observations on the white amur in Arkansas. Hyacinth Control Journal 10:20–22.

Bain, M. B., D. H. Webb, M. D. Tangedal, and L. N. Mangum. 1990. Movements and habitat use by grass carp in a large mainstream reservoir. Transactions of the American Fisheries Society 119:553–561.

Bettoli, P. W., M. J. Maceina, R. L. Noble, and R. K. Betsill. 1993. Response of a reservoir fish community to aquatic vegetation removal. North American Journal of Fisheries Management 13:110–124.

Bonar, S. A. 1990. Efficacy of sterile grass carp (*Ctenopharyngodon idella*) for aquatic plant control in the Pacific Northwest. Doctoral dissertation. University of Washington, Pullman.

Bonar, S. A., G. L. Thomas, S. L. Thiesfeld, G. B. Pauley, and T. B. Stables. 1993a. Effect of triploid grass carp on the aquatic macrophyte community of Devils Lake, Oregon. North American Journal of Fisheries Management 13:757–765.

Bonar, S. A., S. A. Vecht, C. R. Bennett, G. B. Pauley, and G. L. Thomas. 1993b. Capture of grass carp from vegetated lakes. Journal of Aquatic Plant Management 31:168–174.

Boyd, W. A., and R. M. Stewart. 1991. Biocontrol simulations. U.S. Army Corp of Engineers, Waterways Experiment Station, Miscellaneous Paper A-91-3, Vicksburg, Mississippi.

Brown, D. J., and T. G. Coon. 1991. Grass carp larvae in the lower Missouri River and its tributaries. North American Journal of Fisheries Management 11:62–66.

Canfield, D. E., Jr., K. A. Langeland, M. J. Maceina, W. T. Haller, and J. V. Shireman. 1983. Trophic state classification of lakes with aquatic macrophytes. Canadian Journal of Fisheries and Aquatic Sciences 40: 1713–1718.

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361–369.

Cassani, J. R., and W. E. Caton. 1985. Effects of chemical and biological weed control on the ecology of a South Florida pond. Journal of Aquatic Plant Management 23:51–58.

Cassani, J. R., and W. E. Caton. 1986. Efficient production of triploid grass carp (*Ctenopharyngodon idella*) utilizing hydrostatic pressure. Aquaculture 55:43–50.

Cassani, J. R., E. Lasso de la Vega, and H. A. Allaire. In press. An assessment of triploid grass carp stocking rates in small warmwater impoundments. North American Journal of Fisheries Management.

Colle, D. E., J. V. Shireman, R. D. Gasaway, R. L. Stetler, and W. T. Haller. 1978. Utilization of selective removal of grass carp (*Ctenopharyngodon idella*) from an 80-hectare Florida lake to obtain a population estimate. Transactions of the American Fisheries Society 107:724–729.

Colle, D. E., and J. V. Shireman. 1980. Coefficients of condition for largemouth bass, bluegill, and redear sunfish in hydrilla-infested lakes. Transactions of the American Fisheries Society 109:521–531.

Cooke, G. D., E. B. Welch, S. A. Peterson, and P. R. Newroth. 1993. Restoration and management of lakes and reservoirs, 2nd edition. Lewis Publishers, Boca Raton, Florida.

Conner, J. V., R. P. Gallagher, and M. F. Chatry. 1980. Larval evidence for natural reproduction of the grass carp (*Ctenopharyngodon idella*) in the lower Mississippi River. Pages 1–19 *in* L. E. Fuiman, editor. Proceedings of the Fourth Annual Larval Fish Conference. U.S. Fish and Wildlife Service, Biological Services Program FWS-OBS-80/43:1–19.

Durocher, P. P., W. C. Provine, and J. E. Kraai. 1984. Relationship between abundance of largemouth bass and submerged vegetation in Texas reservoirs. North American Journal of Fisheries Management 4:84–88.

Engel, S. 1987. The impact of submerged macrophytes on largemouth bass and bluegills. Lake and Reservoir Management 3:227–234.

Gasaway, R. D., and T. F. Drda. 1976. Effects of grass carp introduction on waterfowl habitat. North American Wildlife and Natural Resources Conference 42: 73–85.

Guillory, V., and R. D. Gasaway. 1978. Zoogeography of the grass carp in the United States. Transactions of the American Fisheries Society 107:105–112.

Hoffman, G. L., and G. Schubert. 1984. Some parasites of exotic fishes. Pages 233–261 *in* W. R. Courtney and J. R. Stauffer, Jr., editors. Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, Maryland.

Kirk, J. P. 1992. Efficacy of triploid grass carp in controlling nuisance aquatic vegetation in South Carolina farm ponds. North American Journal of Fisheries Management 12:581–584.

Leslie, A. J., Jr., L. E. Nall, and J. M. Van Dyke. 1983. Effects of vegetation control by grass carp on selected water-quality variables in four Florida lakes. Transactions of the American Fisheries Society 112:777–787.

Maceina, M. J., M. F. Cichra, R. K. Betsill, and P. W. Bettoli. 1992. Limnological changes in a large reservoir following vegetation removal by grass carp. Journal of Freshwater Ecology 7:81–95.

Malone, J. M. 1984. Triploid white amur. Fisheries (Bethesda) 9(2):36.

Osborne, J. A. 1982. The potential of the hybrid grass carp as a weed control agent. Journal of Freshwater Ecology 1:353–360.

Pflieger, W. L. 1978. Distribution and status of the grass carp (*Ctenopharyngodon idella*) in Missouri streams. Transactions of the American Fisheries Society 107(1):113–118.

Riley, D. M. 1978. Parasites of grass carp and native fishes in Florida. Transactions of the American Fisheries Society 107:207–212.

Robins, C. R. and six coauthors. 1991. Common and scientific names of fishes from the United States and Canada, 5th edition. American Fisheries Society Special Publication 20.

Sanders, L., J. J. Hoover, and K. J. Killgore. 1991. Triploid grass carp as a biological control of aquatic vegetation. U.S. Army Corps of Engineers, Waterways Experiment Station, Aquatic Plant Control Research Program Report A-91-2, Vicksburg, Mississippi.

Savino, J. F., and R. A. Stein. 1982. Predator-prey interactions between largemouth bass and bluegills as influenced by simulated submersed vegetation. Transactions of the American Fisheries Society 111: 255–266.

Shireman, J. V., D. E. Colle, and D. E. Canfield. 1985. Efficiency and cost of aquatic plant control in small ponds. Aquatics 6:14–20.

Shireman, J. V., and C. R. Smith. 1983. Synopsis of biological data on the grass carp *Ctenopharyngodon idella* (Cuvier and Valenciennes, 1844). FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis 135.

Sutton, D. L., and V. V. Vandiver, Jr. 1986. Grass carp—a fish for biological management of hydrilla and other aquatic weeds. University of Florida, Institute of Food and Agricultural Sciences Bulletin 867, Gainesville.

Swanson, E. D., and E. P. Bergerson. 1988. Grass carp stocking model for coldwater lakes. North American Journal of Fisheries Management 8:284–291.

Thompson, B. Z., R. J. Wattendorf, R. S. Hestand, and J. L. Underwood. 1987. Triploid grass carp production. Progressive Fish-Culturist 49:213–217.

Van Eenennaam, J. P., R. K. Stocker, R. G. Thiery, N. T. Hagstrom, and S. I. Doroshov. 1990. Egg fertility, early development and survival from crosses of diploid female × triploid male grass carp (*Ctenopharyngodon idella*). Aquaculture 86:111–125.

Wiley, M. J., P. P. Tazik, and S. T. Sobaski. 1987. Controlling aquatic vegetation with triploid grass carp. Illinois Natural History Survey, Circular 57, Champaign.

Zimpher S. P., C. F. Bryan, and C. H. Pennington. 1987. Factors associated with the dynamics of grass carp larvae in the lower Mississippi River Valley. American Fisheries Society Symposium 2:102–108.