Use of Triploid Grass Carp to Reduce Aquatic Macrophyte Abundance in Recreational Fishing Ponds

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Abstract: Triploid grass carp (*Ctenopharyngodon idella*) were stocked at densities of 25 (low), 50 (medium), and 75 (high) fish/vegetated hectare into 9 0.16- to 2.83-ha Texas panhandle ponds to evaluate stocking densities that may reduce, but not eradicate, submersed aquatic macrophytes. Prior to stocking, the ponds had 50%–100% areal coverage of macrophytes. The macrophyte communities included *Chara* sp., *Ceratophyllum demersum, Myriophyllum spicatum, Najas guadalupensis,* and *Potamogeton* spp. The high stocking density eliminated macrophytes in ≤ 13 months. Low stocking densities did not reduce areal coverage of aquatic vegetation 2 or 5 years after stocking. Triploid grass carp stocked at medium densities reduced areal coverage of macrophytes by 27% after 2 years and 42% after 5 years. Our results indicate that triploid grass carp can reduce macrophytes without eradicating them and percentage areal coverage is an effective basis for prescribing stocking rate.

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Rooted aquatic vegetation (macrophytes) can benefit fish and fisheries by increasing the abundance of macroinvertebrate prey, providing spawning substrate for some fishes, providing shelter for small fish vulnerable to predation, and affecting fish distribution and improving angler catch rates (Noble 1980, Flickinger and Bulow 1993). However, high densities and extensive areal coverage of macrophytes can disrupt predator-prey interactions, cause deleterious changes in water quality, and interfere with diverse human uses of the water body.

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Macrophytes can be controlled by mechanical, chemical, and biological methods. The grass carp is an effective biological control of many macrophyte species (Shireman and Smith 1983, Cooke et al. 1993), and grass carp provide less expensive and longer lasting macrophyte control than mechanical or chemical methods (Shireman 1982, Shireman et al. 1985, Cooke et al. 1993). Widespread use of grass carp has been constrained by the potential for uncontrolled reproduction of this herbivore and subsequent unwanted reduction of desirable macrophytes. Development of sterile triploid grass carp has removed the threat of unwanted reproduction (Allen and Wattendorf 1987, Wiley et al. 1987). Vegetation consumption by triploid and diploid grass carp are essentially the same; hence, the triploid grass carp is an effective aquatic macrophyte management tool that minimizes uncontrolled reproduction (Wattendorf and Anderson 1984, Wiley and Wike 1986, Allen and Wattendorf 1987).

Although grass carp (or triploid grass carp) are an effective tool for macrophyte reduction, introductions typically have resulted in "all-or-none" control of macrophytes (Cassani 1995, Leslie et al. 1996); thus, management to some desired, intermediate level of aquatic vegetation was rarely achieved. However, stocking densities usually were based on surface area of water, not the amount of vegetation (Leslie et al. 1996). Wiley et al. (1987) developed a model that uses vegetated area to predict triploid grass carp stocking rate to reduce macrophytes. Recent evaluations of grass carp with stocking rates based on biomass of vegetation have shown that macrophytes can be reduced without being eradicated (Bonar et al. 1993, Cassani et al. 1995). The ability to stock grass carp to reduce macrophytes without eliminating them expands the utility of grass carp for macrophyte management. However, estimating macrophyte biomass is difficult and imprecise, even with the proper equipment. The objective of this research was to evaluate aquatic macrophyte reduction by triploid grass carp stocked at different densities based on areal estimates of plant coverage.

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Methods

This research was conducted in 9 privately owned ponds in the Texas panhandle (Donley, Gray, Oldham, and Wheeler counties). The ponds were 0.16- to 2.83-ha with maximum depths of 2.0–4.0 m. All ponds were managed for recreational fishing. The fish communities included channel catfish (*Ictalurus punctatus*), green sunfish (*Lepomis cyanellus*), bluegill (*L. macrochirus*), redear sunfish (*L. microlophus*), and largemouth bass (*Micropterus salmoides*). All ponds contained dense growths of *Chara* sp., *Ceratophyllum demersum, Myriophyllum spicatum, Najas guadalupensis,* or *Potamogeton* spp. for at least 2 years prior to the research. These ponds received no chemical macrophyte treatment after 1989.

The perimeter of each pond was mapped using standard surveying procedures and fixed transects equally distributed throughout the pond were established to measure areal coverage of aquatic macrophytes. Approximately monthly during May 1991 through September 1992, percent areal coverage of macrophytes was estimated along the transects with a recording fathometer (Maceina and Shireman 1980) operated from a small boat powered by an electric trolling motor. Fathometer tracings were analyzed to determine presence ("hits") or absence ("misses") of macrophytes every 0.3 m along each transect. If a transect could not be completed due to impassable shallow water, dense macrophyte growth, or any other obstruction, the remaining length of the transect and the proportion of macrophyte coverage along that length of the transect were visually estimated. These visual estimates were converted to "hits" by multiplying the estimated proportion of macrophyte coverage by the estimated remaining transect length/0.3 m. Similarly, the visual estimates were converted to "misses" by multiplying the estimated proportion of open water (1 − the proportion of macrophyte coverage) by the estimated remaining transect length/0.3 m. Percent areal coverage of macrophytes was calculated by dividing the number of "hits" by the total number of "hits" and "misses" for each pond.

It was necessary to stock triploid grass carp in March 1991, 2 months earlier than planned and prior to quantification of macrophyte areal coverage by the above method. To determine stocking number, we made visual estimates of the percent areal coverage of vegetation in each pond. Similarity of these estimates with the measurements of percent areal coverage made in May 1991 with the recording fathometer indicate the visual estimates were accurate approximations of the percent areal coverage (see Results and Discussion). Percent areal coverage was again estimated by visual approximation in September 1995 to assess the long-term effects of the stocking rates.

Plant community composition was measured each time macrophyte coverage was measured during May 1991 to April 1992. Fifteen floating markers were randomly dropped along the transects at water depths of 0–1 m, 1–2 m, and >2 m. At each marker, a macrophyte sample was obtained with a grappling device. All species collected in each sample were identified and assigned a percent relative volume by visual estimation. Plant community composition was calculated as mean percent relative volume of all samples taken from a pond on a sampling date.

Triploid grass carp were stocked by the Texas Parks and Wildlife Department (TPWD) in March 1991. All fish were certified as triploids by TPWD (W. Harvey, pers. commun.). The triploid grass carp averaged 440 m total length (range 392–490) and 0.97 kg (range 0.88–1.06). Three randomly selected ponds were stocked at each of 3 densities: 25 fish/vegetated hectare (low density); 50 fish/vegetated hectare (medium density); and 75 fish/vegetated hectare (high density). All ponds had at least 50% areal coverage of macrophytes at the time of stocking.

Two or 3 grazing exclosures were randomly placed in the littoral zone of each pond in March 1992 to evaluate whether changes in macrophytes were a result of the grass carp or some uncontrolled variable. Each exclosure was 1 × 1 × 2m high. Exclosures were constructed of metal posts and galvanized poultry fencing and were covered to exclude grass carp entry. At the time of placement, 13 of 22 exclosures were void of macrophytes. Monthly from June to September 1992, 4 plants of each species present inside each exclosure were randomly selected and the height of the plant (hydrosoil to apical tip of the plant) measured.

Water temperature and transparency were measured each month when macrophyte areal coverage was measured beginning in March 1991. Water temperature was measured near the center of each pond at 0.1 m depth. Transparency was measured with a Secchi disc at the deepest location in each pond and expressed as percent change from initial value.

The effects of stocking density on macrophyte areal coverage, plant height, water temperature, and water transparency were tested by repeated measures analysis of variance because the ponds were sampled throughout time (Maceina et al. 1994). Because percent areal coverage of macrophytes and water transparency differed among ponds at the start of the experiment, macrophyte coverage and water transparency were expressed as percent change from initial values. Least-squares means tests were used to separate means following a significant F-test.

Results

From March 1991 to September 1992, macrophyte coverage decreased an average of 2.7% in the low stocking density ponds, 27.2% in the medium stocking density ponds, and 100% in the high stocking density ponds (Fig. 1). Percent reduction of macrophyte coverage during May 1991 to September 1992 differed significantly among treatments (F = 20.40, 2,6 df, P = 0.0021); percent reduction was greater in the high stocking density ponds than in the medium or low stocking density ponds, but percent reduction did not differ between the low and medium stocking density ponds. When inspected in September 1995 (5 summers after stocking), the low stocking density ponds had approximately 100% areal coverage of macrophytes, the high stocking density ponds were void of macrophytes except in the exclosures, and the medium stocking density ponds had 25%, 40%, and 60% areal coverage of macrophytes.

Six of the 9 ponds had macrophyte communities containing ≥2 plant taxa at the time of grass carp stocking (Fig. 2). The composition of the macrophyte communities in these ponds changed following grass carp stocking. *Chara* decreased in 5 of these 6 ponds, while relative volume of *Ceratopohyllum demersum, Najas guadalupensis, Potamogeton crispus, P. illinoensis, P. nodosus,* and *P. pectinatus* increased or changed little in the low and medium stocking density ponds. Three ponds that contained only *Myriophyllum spicatum* at the time of stocking remained monotypic through April 1992.

Two months after placement, macrophytes were present in the exclosures in all ponds, and macrophytes remained in all exclosures through September 1992. Average height of macrophytes inside the exclosures during June–September ranged from 631 mm in the medium stocking density ponds to 694 mm in the high density ponds and did not differ among the 3 stocking densities (F = 0.07, 2,6 df, P = 0.9343).

Water temperatures ranged 7–28 C and followed similar seasonal trends in all ponds. We found no significant differences (F = 0.045, 2,6 df, P = 0.6548) in water

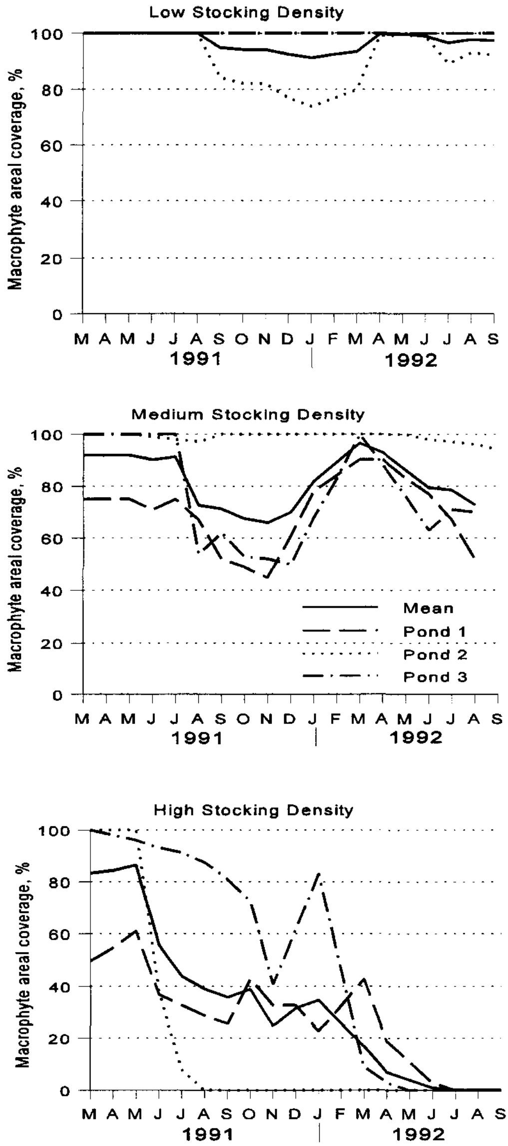

Figure 1. Macrophyte areal coverage (as a percentage of pond surface area) during March 1991 to September 1992 in ponds stocked with triploid grass carp at low (25/vegetated hectare), medium (50/vegetated hectare), and high (75/vegetated hectare) densities.

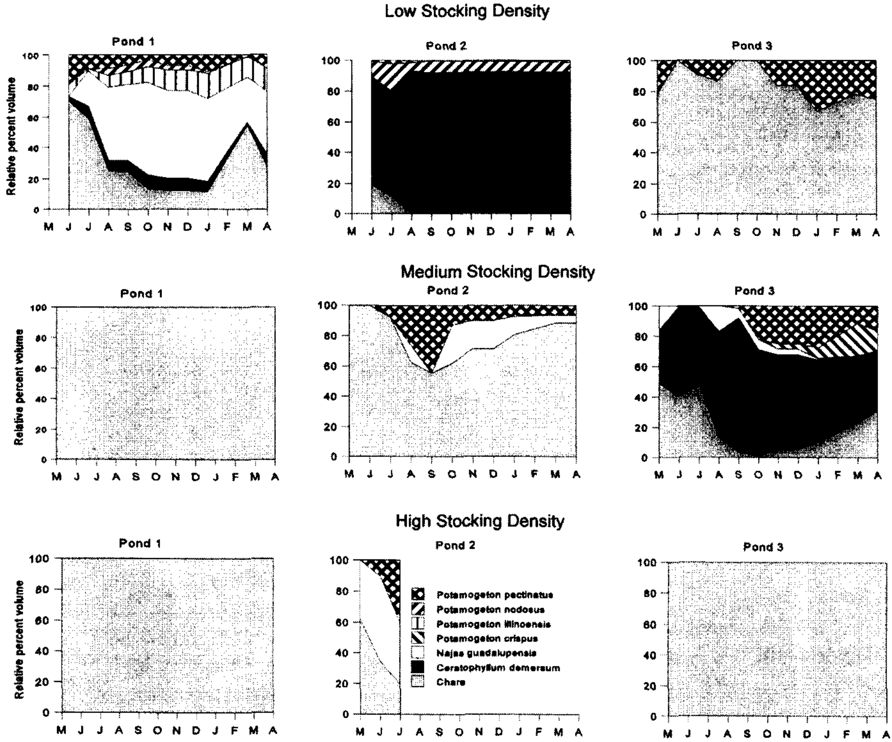

Figure 2. Relative percent volume of macrophyte taxa in ponds stocked with triploid grass carp at low (25/vegetated hectare), medium (50/vegetated hectare), and high (75/vegetated hectare) densities during May 1991 to April 1992. No macrophytes remained in the high stocking density Pond 2 after July 1991.

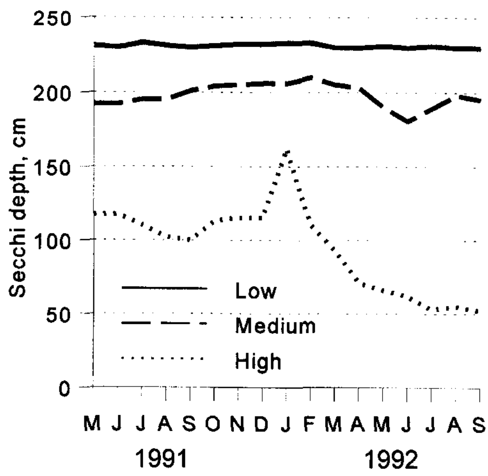

Figure 3. Mean water transparency (Secchi depth, cm) during May 1991 to September 1992 in ponds stocked with triploid grass carp at low (25/vegetated hectare), medium (50/vegetated hectare), and high (75/vegetated hectare) densities.

temperature among ponds stocked at different grass carp densities. Water transparency remained similar in the low and medium stocking density ponds but decreased >50% during the second year after stocking in the high stocking density ponds (Fig. 3). Percent change from initial Secchi depth after grass carp stocking in the high stocking density ponds differed from the change in the medium and low stocking density ponds (F = 9.44, 2,6 df, P = 0.0140).

Discussion

The necessity to stock the triploid grass carp earlier than anticipated required visual estimation of areal coverage of macrophytes. The visually estimated coverage was similar or the same as the coverage estimated by transect sampling in all 9 ponds 2 months later. During this time, the water temperature increased from 15 to 22 C, a temperature range at which grass carp have relatively low to moderately high feeding rates (Edwards 1974, Colle et al. 1978, Clugston and Shireman 1987). Hence, some vegetation reduction would be expected; however, plant growth likely was relatively rapid during these 2 months in the spring. Therefore, we expect little net change in macrophyte areal coverage during March–May and believe that the similarities between visually estimated macrophyte coverage in March and transect-estimated macrophyte coverage in May indicate that percent areal coverage of macrophytes can be visually estimated with reasonable accuracy in small, shallow ponds with relatively high water clarity.

Triploid grass carp averaging 440 mm long and weighing approximately 1 kg when stocked eradicated aquatic macrophytes from small ponds in the Texas panhandle in ≤13 months when stocked at 75 fish/vegetated hectare. Diploid grass carp stocked at 74 fish/vegetated hectare into 8,500-ha Lake Conroe, Texas, eliminated macrophytes in 2 years (Klussman et al. 1988). Wattendorf and Anderson (1984) found triploid and diploid grass carp had similar macrophyte consumption rates. Hence, macrophyte reduction rates would be expected to be similar between triploid and diploid grass carp. The slower time to eradicate macrophytes in Lake Conroe than in our experimental ponds may have resulted from the smaller size of grass carp stocked into Lake Conroe (grass carp vegetation consumption is a function of body weight [e.g., Chapman and Coffey 1971, Osborne and Sassic 1981]), the greater biomass of macrophytes per vegetated hectare in Lake Conroe (macrophytes grew at greater depths in Lake Conroe than in our experimental ponds), or differences in macrophyte communities between Lake Conroe, where *Hydrilla verticillata* was the dominant macrophyte, and our ponds.

We found 25 triploid grass carp/vegetated hectare reduced density of *Chara* but did not substantially reduce the areal coverage of macrophytes. Hence, 25 grass carp/vegetated hectare probably is too low a stocking density to reduce macrophyte coverage in ponds in the temperate climate of the Texas panhandle.

We found 50 triploid grass carp/vegetated hectare produced slow and limited reduction of macrophytes. Kirk (1992) found 50 triploid grass carp/hectare failed to reduce macrophytes in 0.1- to 5.7-ha South Carolina ponds within 2 years. Percent macrophyte coverages for these ponds were not known (J. P. Kirk, pers. commun.); however, at a stocking rate of 50 fish/hectare (total pond area), the ponds received at least 50 grass carp/vegetated hectare. In a parallel study, Kirk (1992) found that the 1-month mortality rate for these grass carp was 28%–43%; hence, mortality may have influenced the effectiveness of the triploid grass carp by reducing stocking density. We did not measure survival of the stocked grass carp. The grass carp were transported during cool weather (<15 C air temperature) and stocked into cool (<15 C) water, so stocking mortality was assumed to be minimal. The pond owners checked their ponds regularly for 2 weeks after stocking and reported no dead grass carp. The newly stocked grass carp were large enough to be readily visible if they died and floated. No dead grass carp were seen during March 1991–September 1992. The grass carp we stocked were larger than the length expected to be consumed by largemouth bass present in these ponds (Shireman et al. 1978), and piscivorous birds were relatively scarce around the ponds. Overall, we believe grass carp survival was high during at least the first 2 years after stocking.

The reduction in relative abundance of *Chara* suggests triploid grass carp prefer this plant. Although some researchers found *Chara* was one of the least preferred species (e.g., Opuszynski 1972, Pine and Anderson 1991), other researchers found diploid and triploid grass carp readily consumed *Chara* (e.g., Stevenson 1965, Fowler and Robson 1978, Swanson and Bergerson 1988, Cassani et al. 1995). Preferential feeding and changes in plant community composition following grass carp stocking were also observed in other studies (e.g., Fowler and Robson 1978, Mitzner 1978, Nall and Schardt 1980, Cassani et al. 1995). Except for *Myriophyllum spicatum*, the other macrophytes found in our ponds are preferred or readily consumed by grass carp (e.g., Shireman and Smith, 1983, Swanson and Bergerson 1988, Bonar et al. 1993, Cooke et al. 1993). Based on a review of the literature, Shireman and Smith (1983) concluded all palatable macrophytes are usually consumed when sufficient grass carp are present. Although *Myriophyllum spicatum* appeared most resistant to reduction, we found reduction of all macrophyte species when triploid grass carp were stocked at 75 fish/vegetated hectare.

Clearly there is variation in the amount and rate of macrophyte reduction obtained with grass carp. Cassani (1995) offers valuable suggestions for reducing and explaining some of the variation in results among grass carp stocking programs. Similar to the variation in both the amount and rate of macrophyte reduction in the 9 ponds we studied, Swanson and Bergerson (1988) also found variation in triploid grass carp effectiveness in Colorado ponds; fish stocked at 47/vegetated hectare reduced macrophytes in a 5.7-ha pond, but macrophyte biomass increased in ponds stocked with 37, 49, and 84 triploid grass carp/vegetated hectare. Until additional information is available about the many physical (e.g., water temperature, length of growing season), chemical (e.g., alkalinity, lake trophic status), and biological (e.g., macrophyte species, macrophyte biomass, macrophyte growth rate, macrophyte energy content, size of grass carp) variables that can affect macrophyte growth and consumption by grass carp, variation in results should be expected.

The reduction in water transparency following macrophyte reduction by grass carp has been observed in several studies (Shireman and Smith 1983, Cooke et al. 1993). We did not measure changes in phytoplankton density; however, other researchers have found increased phytoplankton density after macrophyte elimination (e.g., Miller and King 1984, Maceina et al. 1992). It is interesting to note that substantial changes in water clarity occurred only after the macrophytes were eliminated. Water clarity changed little in the medium stocking density ponds where macrophytes were reduced. Also, water clarity changed little in the high stocking density ponds during the first year when moderate amounts of vegetation remained in 2 of the ponds.

Our results demonstrate that triploid grass carp can be used to reduce macrophytes without achieving total eradication. Stocking rate models, particularly those that include some measure of macrophyte biomass (Swanson and Bergerson 1988, Bonar 1990, Cassani 1995), may serve as good management tools for the effective use of grass carp to manage, as opposed to eradicate, macrophytes. Although macrophyte biomass provides a biologically sound basis for establishing stocking rates, factors affecting macrophyte production (e.g., length of growing season, nutrients) also will likely affect macrophyte reduction by grass carp. Estimating macrophyte biomass is time consuming, imprecise even with extensive sampling (see data in Bonar et al. [1993] and Cassani et al. [1995]), and not readily performed by private pond owners. Considering the variability of the effects of triploid grass carp found in this and other evaluations and the many variables that can affect macrophyte reduction, our results suggest that estimated areal coverage of macrophytes is an effective basis for determining triploid grass carp stocking rate when the management goal is to reduce, not eliminate, macrophytes.

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