Hydrilla Consumption by Triploid Grass Carp[1]

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Abstract: Triploid grass carp (*Ctenopharyngodon idella,* 2n = 72) were found to consume an average of 127 ± 17% of their body weight in fresh hydrilla (*Hydrilla verticillata*) per day. Experimental fish were 199 ± 27 g at the outset, and during the 51-day trial, the 6 fish gained an average of 3.3 ± 0.5 g/day. Total lengths increased from 243 ± 10 mm to 301 ± 15 mm (1.1 ± 0.2 mm/day) during this time. These values are equivalent to results reported by other researchers for diploid grass carp and are 3 to 4 times greater than for triploid hybrid grass carp (*C. idella* X *Hypophthalmichthys nobilis,* 2n = 72) tested in 1983. Food conversion efficiency was 60 ± 8%. Triploid grass carp were also effective in removing hydrilla from 2 0.1-ha hatchery ponds. Fish ($\bar{x}$ = 196 g) were stocked at a rate of 250/ha in 1 pond and 500/ha in the other. At the conclusion of the study 9 months later, hydrilla was absent from the pond, except for within control exclosures. Upon harvesting, 90% of the fish from 1 pond and 96% from the other were recovered. During the test they had grown to a mean weight of 2.1 kg.

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Excessive plant biomass inhibits water usage by boaters, skiers, and fishermen, is aesthetically unpleasant, and can reduce the standing crop of fish (Maceina and Shireman 1982). Herbicide treatments are frequently detrimental to the environment, are expensive, and often must be applied several times a year. Therefore, a biological control agent which would not itself get out of control has long been sought (Swingle 1957).

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Grass carp generally are considered to be the best available biological control agent for aquatic vegetation. When grass carp are stocked at rates proportional to the biomass of aquatic vegetation, and taking into account the system's productivity, grass carp perform well (Gasaway and Drda 1978, Miley et al. 1979, Von Zon 1979). However, uncontrolled spawning and survival of grass carp in some areas could lead to elimination of aquatic plants which are important as fish nursery areas, substrate for invertebrates, and forage for waterfowl. Grass carp have spawned in the Mississippi River (Conner et al. 1980) proving the diploid grass carp is capable of spawning in natural waters of the United States.

Beginning in 1978, interest arose in using hybrid grass carp for aquatic plant control, since it was considered functionally sterile (Buck 1979). Although the hybrid was effectively utilized in some circumstances, it had a slower growth rate, lower plant consumption rate, and greater handling problems than pure grass carp which frequently made the cost benefit ratio unacceptable (Hestand et al. 1983).

High percentages of triploid grass carp were obtained in 1983 for the first time by Malone and Son Enterprises (Lonoke, Ark.). Unlike the hybrid which has a zooplanktivore for a paternal parent, this fish is a pure grass carp. The initial evaluation of ploidy was determined by S. Allen to be 98% based on analyses of 172 fish with a flow cytometer (Malone 1984). In May 1984, the percentage of triploids was confirmed based on erythrocyte nuclear volumes by using a Coulter Counter with Channelyzer on 600 fish received by the Florida Game and Fresh Water Fish Commission. Both groups of fish were hand culled from a spawn which produced approximately 90% triploids, about 28% of the fish were rejected to obtain the effective 8% increase in ploidy (J. Malone, pers. commun.). The 2% of the grass carp which are diploid are of concern, however, due to the large number of fish which likely will be stocked and to grass carp fecundity (e.g. a 3-year-old, 10-kg female has more than a million eggs).

The purpose of this study was to determine the rate at which triploid grass carp consume hydrilla in aquaria and if they could eliminate hydrilla from small ponds. These data were compared to results obtained in 1982 with hybrid grass carp and to literature reports of grass carp feeding efficacy.

Methods

Rates of hydrilla consumption by triploid grass carp were evaluated in 6 300-liter aquaria. Each aquarium was equipped with a substrate filter, a 300-watt submersible heater set at 26° C, a lid, and a black plastic wrapping to prevent visual disturbances.

The triploid grass carp used for this experiment were spawned by Malone and Son Enterprises in 1983, and their ploidy was verified based on erythrocyte nuclear dimensions. At the outset of the experiment, fish were 4- to 5-months-

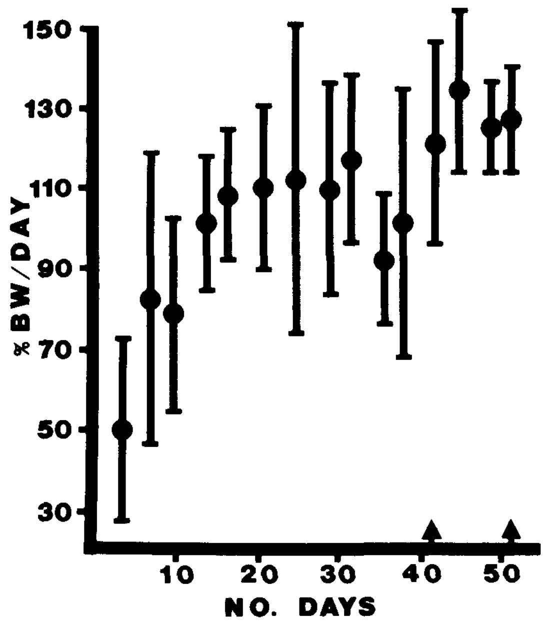

Figure 1. Hydrilla consumed by triploid grass carp as mean percent body weight eaten per fish, per day. Vertical bars represent ±1 standard deviation for 6 fish. Arrows delineate the peak periods.

old and averaged 199 ± 27 g and 243 ± 10 mm total length (TL). A single fish was stocked in each aquarium. Cursory examination revealed no external features which would separate triploid from diploid grass carp.

Hydrilla was obtained locally from ponds and canals, and individual strands were cleaned of periphyton and invertebrates before use. Clumps of hydrilla were held together with a rubber band and, after draining for 8 minutes, were adjusted to 200 g each. Weights were attached to each clump, and 1 to 8 clumps were added to each aquarium based on how much the fish was consuming.

Individual feeding periods were terminated when there was estimated to be less than 1 day's food supply remaining. At that time, hydrilla was removed and weighed, and fresh hydrilla was placed in the aquarium. After each feeding period, 10% to 25% of the water was siphoned out along with accumulated feces, and fresh water was added. Feeding periods each lasted 2 to 4 days for a total of 51 days and 15 periods. Grass carp were again weighed and measured at the conclusion of the trial.

Percent body weight consumed per fish per day (% BW/D) was based on the difference in weight of hydrilla put in and taken out of each tank compared to the grass carp's estimated body weight for that period as determined from a regression of the fish's initial and final weight. The estimate for dry weight of hydrilla consumed was based on a 94% weight reduction of the hydrilla after drying at 70° C for 92 hours (hence, fresh weight x 0.06 = dry weight). Food conversion efficiency was based on weight gain of fish divided by total dry weight of hydrilla consumed multiplied by 100.

For the pond study, 2 0.1-ha hatchery ponds which had a history of excessive hydrilla growth were selected. Hydrilla had in the past grown as much as 7 cm/day in these ponds and reached the surface across the entire pond. Ponds were prepared for stocking by drawing them down and exposing 50% to 70% of the bottom for several weeks. Each pond had 4 cages (1.5 m high, 1 m^2 cross sectional area), 2 of which were used as exclosures and 2 as protection against predators for a single triploid each. The ponds were then reflooded and 1 week later, 1 pond received 25 triploids (250/ha) and the other 50 triploids (500/ha). At stocking, the fish had a mean length of 242 ± 8 mm TL and a mean weight of 196 ± 21 g. The water appeared clear and 50% of the bottom had healthy hydrilla with a height of about 50 cm.

Results

Triploids in aquaria began feeding soon after stocking but did not reach maximum feeding levels until the later feeding periods (Fig. 1). Consumption rates as mean % BW/D for the 6 replicates ranged from 50 ± 23% during the initial stages to 134 ± 18% near the end of the study. The most consumed by any fish during a feeding period was 171% BW/D. Expressed as grams dry weight consumed per fish per day (g DW/D), mean consumption for the 6 replicates varied from a mean of 6.2 ± 2.2 g during the first 4 days to 27.6 ± 3.7 g DW/D during the final period.

During the 51-day experiment, average fish weight increased 84% to 365 ± 44 g or 3.3 ± 0.5 g/day. Average total length increased to 301 ± 15 mm in average increments of 1.1 mm/day. Mean food conversion efficiency was 60 ± 8% (Table 1).

Regular water changes kept water quality at acceptable levels. The pH fluctuated from 7.8 to 8.3 and ammonia from 0.00 to 0.16 mg/liter. Dissolved oxygen levels were always >8.4 ppm when measured. Temperature varied from 24.5° to 27.2° C.

Within 3 months of stocking the ponds, a snorkeler could not find any hydrilla outside exclosures, and exclosures appeared close to their carrying capacity of hydrilla. When the study was terminated after 9 months, there was still no hydrilla outside the exclosures and an increase in phytoplankton turbidity had apparently begun to shade out hydrilla in exclosures, which were at 50% to 75% of their carrying capacity of hydrilla. At the conclusion of

Table 1. Growth and consumption data for 6 triploid grass carp during a 51-day trial. Average consumption rate was based on the last 4 periods for each fish.

Variable	Fish						Mean	SD
	1	2	3	4	5	6		
Initial length (mm TL)	249	228	241	234	254	250	243	10
Initial weight (g)	220	165	190	175	210	235	199	27
Final weight (g)	385	342	329	312	401	422	365	1
Growth/day (g)	3.2	3.5	2.7	2.7	3.7	3.7	3.3	0.5
Consumption (% BW/D)	122	125	115	149	126	123	127	17
Total consumed (g DW)	302	250	232	282	293	313	279	31
Efficiency	55	71	60	49	65	60	60	8

the study, 90% of the fish were recovered from 1 pond and 96% from the other. The fish's mean weight was 2.1 ± 0.3 kg and mean length was 569 ± 24 mm TL. This allows a rough estimate of growth to be calculated as 7 g/day. A subsequent restocking of 5 triploid grass carp has prevented regrowth through the summer.

Discussion

Consumption rates determined for triploid grass carp in this aquaria study were equivalent to or exceeded rates for diploid grass carp as reported in the literature. However, such comparisons must be judged critically due to different experimental factors such as temperature, stocking density, age, sex, and size of fish (Prowse 1971). Grass carp <3 kg were estimated to consume about 100% BW/D in lakes by Shireman and Maceina (1981). Blackburn and Sutton (1971) found that grass carp kept in plastic pools grew more rapidly than those kept in indoor aquaria while being fed hydrilla and naiad (*Najas guadalupensis*). Sutton (1974*a*) then determined that in pools with flow-through water, grass carp ($x = 99$ g) on the average consumed 165% BW/D of hydrilla, while grass carp which averaged 753 g and 1,020 g ate on the average 73% BW/D.

Triploid hybrid grass carp tested under laboratory conditions in circular flow-through tanks consumed about half as much hydrilla (Shireman et al. 1983) as did triploid grass carp in this study. Triploid hybrid grass carp between 210 and 370 mm TL tested under laboratory conditions similar to those used in the present study consumed about a third as much hydrilla as triploid grass carp and averaged only 38% BW/D; moreover, the hybrids only grew 0.01 g/day (Wattendorf and Shafland 1983).

Changes in body weight of 3.3 g/day in this aquaria experiment with 199 g fish was substantially less than the 6.1 g/day found by Sutton (1974*a*) with 153 g grass carp in pools. It was also less than the 6.5 g/day found for siblings of the fish studied here which were placed in a 0.1-ha pond for 53 days with muskgrass (*Chara* spp.) and southern naiad available to them (unpubl. data), and it was less than half the growth rate of fish in the hydrilla pond study. This suggests that triploid grass carp eat at a substantially greater rate in ponds than in aquaria.

Although stocking rates (250/ha, 500/ha) used in the pond study were excessive, they clearly show that triploid grass carp can remove hydrilla effectively even from ponds with prolific hydrilla growth. At 250 hybrids/ha, hybrid grass carp could not prevent hydrilla from reaching the surface all across these ponds. At 420 hybrids/ha, they were able to eliminate the hydrilla (Wattendorf 1982). Pond studies with normal diploid grass carps showed that high stocking rates were necessary to eliminate heavy infestations of hydrilla (Sutton 1974*b*), and that 137 to 360 grass carp/ha were successful in removing hydrilla from 0.08-ha ponds in Orange County, Florida (Sutton et al. 1979). The same researchers found that 100 grass carp/ha ($\bar{x} = 500$ g) removed hydrilla from a 0.4-ha pond in 6 months. These fish grew 6.6 g/day and 98% survived. Subsequent stocking with 12 grass carp/ha ($\bar{x} = 1890$ g) prevented regrowth for at least 9 months. Thus it appears that triploid grass carp are also growing, surviving, and consuming hydrilla in small ponds in a manner equivalent to their diploid progenitors.

No induced triploid fish has ever been documented as having reproduced, and histological studies have shown they develop severely altered gonads (Gervai et al. 1980, Wolters et al. 1982). The few natural populations of triploid fish that do perpetuate themselves do so by highly adapted strategies which are not likely to occur spontaneously in induced populations (Cimino 1972). Therefore, it is comparatively safe to assume that triploid fish will be sterile (Yamazaki 1983, Thorgaard 1983). To alleviate the concern of uncontrolled reproduction by the few potentially prolific diploid grass carp, the authors developed a technique using a Coulter Counter with Channelyzer for evaluating ploidy which is accurate, rapid, and relatively inexpensive (manuscript in preparation). With this equipment, a 4-man team can examine at least 2,000 fish per day for ploidy, thus making a certification program requiring 100% triploidy feasible.

In conclusion, triploid grass carp should provide a new tool for the fisheries manager which is comparable to diploid grass carp in controlling problem growth of aquatic plants while being environmentally safer. Of course, the hypothesized sterility of these fish does not preclude problems associated with overstocking, such as plankton blooms subsequent to elimination of all aquatic macrophytes in the stocked area.

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