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COMMUNICATIONS

Growth Comparisons of Diploid and Triploid Grass Carp under Varying Conditions

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Abstract.—Growth of fry and fingerling diploid and triploid grass carp (*Ctenopharyngodon idella*) was evaluated under a variety of experimental situations that involved high and low stocking densities and various levels of food availability. Diploid grass carp grew faster and had significantly ($P < 0.05$) higher condition factors in every situation where they were grown together with triploid grass carp. When diploid and triploid grass carp were grown in separate pools and fed to satiation with duckweed, there were no significant differences ($P < 0.05$) in growth, condition factors, food conversions, or rates of food consumption. The difference in the rate of growth between diploid and triploid grass carp can be exploited to presegregate diploid from triploid fish, thus reducing the time spent certifying ploidy with a Coulter Counter®.

Importation and use of grass carp (*Ctenopharyngodon idella*) as a biological control agent for aquatic weeds has been limited in many areas, especially in North America, because of the species' potential for unwanted reproduction (Miller and Decell 1984). The recent development of triploid grass carp (generally considered to be sterile) provides a viable alternative to diploid grass carp in areas where reproduction is unwanted.

Induction of triploidy in grass carp or grass carp hybrids (female grass carp × male bighead carp *Hypophthalmichthys nobilis*) has rarely exceeded 90% on a consistent basis and can range from less than 1% to an estimated 100% with the same or similar inducements (Cassani et al. 1984; Cassani and Caton 1985). Use of triploid hybrid grass carp has generally been curtailed due to problems associated with growth, food consumption, and survival (Osborne 1982; Cassani and Caton 1983; Shireman et al. 1983). In Florida, the ploidy of all triploid grass carp must be certified with the use of a Coulter Counter® or similar instrument before any fish are stocked for aquatic weed control. Presegregation of triploid from diploid individuals based on morphological comparisons is not practical; the animals look too similar. Ploidy testing of fish populations with low percentages of triploids can be very time-consuming.

The purpose of this study was to determine what environmental factors could create a differential growth rate between diploid and triploid grass carp. If triploid fish could be reliably and practically segregated from diploid fish based on a difference in growth or condition, this would increase the efficiency of final ploidy determinations with a Coulter Counter.

Methods

Total lengths and weights of diploid and triploid grass carp were evaluated under a variety of conditions to determine which environmental factors affect growth and to what degree.

Low density: fry.—A population of grass carp from a single spawn (14–25 mm total length), estimated to be approximately 50% triploid, was introduced into a fertile nursery pond at the rate of approximately 44,000 fry/hectare. Fish were fed finely ground formulated feed (32% protein) initially. They were provided with generous quantities of duckweed (*Wolffia* sp. and *Lemna* sp.) when they reached 40–50 mm in total length (about 13 d into the 53-d test period). At the end of the test period, the fish were weighed and measured. Ploidy was determined by extracting a small volume of erythrocytes from the caudal artery and testing the cells with a Coulter Counter (Wattendorf 1986).

High density: fingerlings.—Approximately 6,000 grass carp fingerlings, 60–100 mm in total length, were stocked in a nursery pond at a rate of 267,000/hectare. These fish were fed duckweed several times a week at a rate considerably less than that required for sustained growth. The food was completely consumed in 6–8 h. During a 7-week period, weights and total lengths were determined for 36 triploid and 80 diploid individuals that had been randomly selected. Ploidy was determined with a Coulter Counter.

Low density: fingerlings.—Fifty diploid and 50 triploid grass carp fingerlings, 130–160 mm in total length, were stocked together in a pond at

a rate of 4,400/hectare. Fish were fed duckweed 5 d/week. The quantity fed was somewhat less than satiation (100% consumption in 12–15 h). Total lengths and weights were determined for individual fish at the beginning and at the end of the 75-d test period. Ploidy was determined with a Coulter Counter.

Pool study: fingerlings.—Fifty diploid and 50 triploid grass carp fingerlings, averaging 130–175 mm in total length, were grown separately in 3.6-m-diameter (7,500-L) greenhouse pools. Both pools were maintained in the same manner, involving aeration, a flushing rate of one water exchange every 15 h, and periodic treatments with a malachite green–formaldehyde solution as a prophylactic against external parasites and pathogens. Fish in the pools were fed to satiation 6 d/week with duckweed (*Lemna* sp.) and were acclimated to pool conditions for 6 d before the study began. This segment of the study was conducted concurrently with the low-density fingerling segment. Fresh duckweed was weighed after it was spun in a washing machine at approximately 500 revolutions/min for 5 min. Duckweed dry weight was determined after 10 samples of preweighed fresh duckweed were dried in an oven at 70°C for 48 h.

Total lengths and weights of individual fish were recorded initially and after the next six 2-week periods. Fish were anesthetized with tricaine methane sulfonate (MS-222) prior to length and weight measurements. A YSI model 57 dissolved-oxygen meter was used to record oxygen and temperature in pools and ponds during the early morning and afternoon daily. Means for the several variables were compared between diploid and triploid fish groups by two-sample t-tests ($P < 0.05$).

Results

Low Density: Fry

Mean total lengths of diploid and triploid grass carp fry (14–25 mm), grown together in the same pond for 53 d at a relatively low density, were significantly different ($P < 0.05$). Length-frequency distributions were determined for random samples of 58 diploid and 58 triploid fish (Figure 1). Mean total lengths (±SD) were 104.6 ± 18.7 mm for diploid fish and 83.3 ± 15.3 mm for triploid fish. Mean weights (±SD) were 16.9 ± 8.4 g and 7.8 ± 4.7 g for diploid and triploid fish, respectively. Diploid fish also had a significantly higher mean condition factor (1.32 ± 0.16) than triploid fish (1.19 ± 0.17). Regressions of length (L, mm) against weight (W, g) produced from these data confirmed that diploid fish were in better condition:

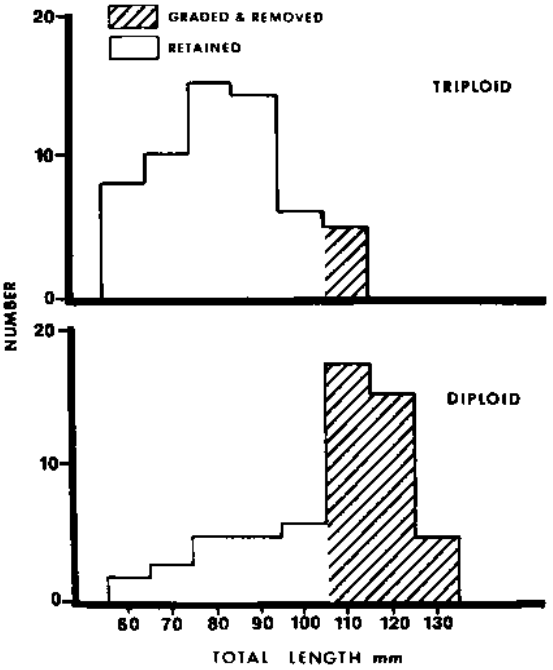

FIGURE 1.—Length-frequency distributions for 58 diploid and 58 triploid grass carp grown together for a 53-d period. Grading and removing fish longer than 105 mm (hatched area) decreased the number of diploid fish by 63.8%.

triploid,

$$\log_{10} W = -5.311 + 3.205 \log_{10} L; \quad r = 0.970;$$

diploid,

$$\log_{10} W = -5.827 + 3.468 \log_{10} L; \quad r = 0.987.$$

Mean pond temperature and dissolved oxygen concentration during the experimental period were 29.3 ± 1.7°C (SD) and 5.9 ± 3.4 mg/L, respectively.

High Density: Fingerlings

In the high-density, sparse-food situation, the mean total length of diploid fish (92.3 ± 16.9 mm) was again greater than that of triploid fish (80.5 ± 6.4 mm) but not significantly so ($P > 0.05$). However, the mean diploid condition factor (1.08 ± 0.08) was significantly greater than the triploid condition factor (0.95 ± 0.08). During this period, mean temperature and dissolved oxygen concentration were 28.1 ± 2.4°C and 8.1 ± 3.0 mg/L, respectively.

TABLE 1.—Growth, condition factor, food consumption, and food conversion of diploid and triploid grass carp grown either separately in pools or together in a pond at low density for 75 d. Values are means ± SD; lengths are total lengths in millimeters; weights are in grams. Values along a row (and in columns for mean condition factors) within pools or pond without a letter in common are significantly different ($P < 0.05$).

Variable	Segregated in pools		Unsegregated in pond	
	Diploids	Triploids	Diploids	Triploids
Mean length—start	138.7±13.5 z	152.1±7.1 y	133.6±8.1 z	149.1±7.0 y
Mean weight—start	33.7±10.5 z	44.6±13.5 y	28.6±5.7 z	44.1±6.3 y
Mean length increase per 14-d interval	23.7±4.9 z	20.7±7.3 z		
Mean weight increase per 14-d interval	36.3±18.9 z	34.2±14.2 z		
Mean % length increase per 14-d interval	13.2±4.5 z	11.0±5.1 z		
Mean % weight increase per 14-d interval	46.1±22.0 z	39.2±29.0 z		
Length increase—total period	118.3	103.6	191.4	178.9
Weight increase—total period	181.7	171.0	379.5	347.6
Mean condition factor—start	1.26 z	1.27 z	1.19 z	1.32 y
Mean condition factor—end	1.27 z	1.29 z	1.19 z	1.11 x
Mean dry food conversion[a] per 14-d interval	2.2±0.3 z	2.8±1.4 z		
Mean fresh food conversion[a]	34.2±4.5 z	45.8±22.5 z		
Mean food consumption % body weight/d	88.2±31.8 z	81.5±22.1 z		

[a] Average fresh or dry weight food fed (kg) ÷ average weight gain per individual (kg).

Low Density: Fingerlings

During the low-density, abundant-food phase of the study, diploid fish again grew at a faster rate than triploid fish (Table 1). Diploid fish condition factor did not change significantly during this period. By the end of the study, the condition factor for triploid fish had decreased significantly and was significantly lower than that for diploid fish. The growth rates during this period averaged 5.1 g/d for diploids and 4.6 g/d for triploid fish; these are relatively high growth rates for grass carp of this size. Mean pond temperature and dissolved oxygen concentration were 26.0 ± 2.5°C and 7.2 ± 3.5 mg/L, respectively.

Pool Study: Fingerlings

When diploid and triploid fish were cultured in separate pools with unlimited food, diploid fish once again grew faster (2.4 versus 2.3 g/d: Table 1), although not significantly so ($P > 0.05$). Diploids and triploids did not differ significantly in mean condition factor, food conversion, or food consumption. Mean temperature for both pools was 26.3°C (range, 23.0–28.2°C). Mean dissolved oxygen concentrations were 7.7 ± 0.41 and 7.9 ± 0.33 mg/L in the triploid and diploid fish pools, respectively.

Discussion

In every test situation where diploid and triploid grass carp were grown together, diploid fish demonstrated an overall faster growth rate and a significantly higher condition factor than triploid fish. When fingerling fish were overstocked and underfed, the discrepancy between mean diploid and triploid total lengths was least. The greatest difference between diploid and triploid mean total length occurred when fry were grown at a relatively low density with abundant food (Figure 1). No significant differences in growth, condition, food conversion, or food consumption occurred when diploid and triploid fish were grown independently under the same culture conditions, when food was not limited. The combined effect of a slightly more efficient food conversion and higher consumption rate of the diploid fish is probably responsible for their faster growth when grown with triploid fish competing for the same resources.

Gervai et al. (1980) reported that the growth rate of triploid juvenile common carp (*Cyprinus carpio*) feeding ad libitum was not significantly different from that of diploid fish. A comparison of growth for diploid and triploid threespine sticklebacks (*Gasterosteus aculeatus*) indicated that triploid fish grew no faster than diploid individuals (Swarup 1959). Benfey and Sutterlin (1984) found no significant difference in the weight of diploid and triploid Atlantic salmon (*Salmo salar*) but triploid fish had a lower condition factor. Faster growth has been reported for 8-month-old triploid channel catfish (*Ictalurus punctatus*) and for 14-week-old triploid blue tilapia (*Tilapia aurea*) compared to diploid individuals (Valenti 1975; Wolters et al. 1982).

The faster growth rate of diploid than of triploid grass carp can be useful for distinguishing one group

from the other and for reducing the time spent handling and certifying the triploids. With reference to the length-frequency distributions in Figure 1, grading and discarding fish longer than 105 mm would have reduced the number of diploid fish by 63.8% and increased the percentage of triploids remaining from 50 to 71.6%. Also, differences in condition between diploid and triploid fish can be visually detected at total lengths of 300 mm or more. The reliability of sorting diploid from triploid fish based on the visual perception of plumpness was greater than 90% after 10 or 15 min of practice.

A decision to incorporate large-scale grading as a presegregation technique depends on the value of time and labor relative to the value of triploid fish lost in the grading process. We recommend this procedure when the proportion of triploid fish is low (i.e., <50%) or when the number of available triploid fish greatly exceeds the number needed. For example, we would recommend this procedure in a situation where 500,000 larvae will yield 25,000 triploids (5%) but only 15,000 triploids are needed.

In conclusion, growth rate differences in diploid and triploid grass carp fingerlings can be used to presegregate diploid from triploid grass carp when the fish are grown in low-density, abundant-food situations that sustain rapid growth (2–5 g/d). Segregating diploid and triploid grass carp cultured under these conditions when fish have total lengths of 50–140 cm can result in a considerable savings in handling time and elimination of at least 50% of unwanted diploids. Visual sorting of triploid fish, which are less plump, can be accomplished with larger fish (>300 mm total length) with reasonably high accuracy but this procedure is more time consuming because each individual must be examined.

References

Benfey, T. J., and A. M. Sutterlin. 1984. Growth and gonadal development in triploid landlocked Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 41:1387–1392.

Cassani, J. R., and W. E. Caton. 1983. Feeding behaviour of yearling and older hybrid grass carp. Journal of Fish Biology 22:35–41.

Cassani, J. R., and W. E. Caton. 1985. Induced triploidy in grass carp *Ctenopharyngodon idella* Val. Aquaculture 46:37–44.

Cassani, J. R., W. E. Caton, and B. Clark. 1984. Morphological comparisons of diploid and triploid hybrid grass carp, *Ctenopharyngodon idella* ♀ × *Hypophthalmichthys nobilis* ♂. Journal of Fish Biology 25:269–278.

Gervai, J., S. Peter, A. Nagy, L. Horvath, and V. Csanyi. 1980. Induced triploidy in carp, *Cyprinus carpio* L. Journal of Fish Biology 17:667–671.

Miller, A. C., and J. L. Decell. 1984. Use of the white amur for aquatic plant management. U.S. Army Corps of Engineers Waterways Experiment Station, Instruction Report A-84-1, Vicksburg, Mississippi.

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

Shireman, J. V., R. W. Rottman, and F. J. Aldridge. 1983. Consumption and growth of hybrid grass carp fed four vegetation diets and trout chow in circular tanks. Journal of Fish Biology 22:685–693.

Swarup, H. 1959. Effects of triploidy on the body size, general organization and cellular structure in *Gasterosteus aculeatus* (L.). Journal of Genetics 56:143–155.

Valenti, R. J. 1975. Induced polyploidy in *Tilapia aurea* (Steindachner) by means of temperature shock treatment. Journal of Fish Biology 7:519–528.

Wattendorf, R. J. 1986. Rapid identification of triploid grass carp with a Coulter Counter and channelyzer. Progressive Fish-Culturist 48:125–132.

Wolters, W. R., G. S. Libey, and C. L. Chrisman. 1982. Effect of triploidy on growth and gonad development of channel catfish. Transactions of the American Fisheries Society 111:102–105.