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Food Preferences, Food Intake, and Growth of the F_1 Hybrid of Grass Carp ♀ × Bighead Carp ♂

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Abstract

Hybrid carp from the cross grass carp *Ctenopharyngodon idella* ♀ × bighead carp *Aristichthys nobilis* ♂ preferred filamentous algae and *Najas guadalupensis* over *Ceratophyllum demersum*. Medium-sized (273 g) and large hybrids (360 g) consumed more plant material and grew faster than small hybrids (77 g) at 14 and 22 C in aquaria. Aquarium data suggest that it will require at least twice as many hybrids as grass carp of the same size to obtain the same level of vegetation control.

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Grass carp *Ctenopharyngodon idella* have been imported from Asia to the United States for long-term aquatic weed control in temperate and southern waters (Guillory and Gasaway 1978). These herbivores are fast-growing and consume more than 100% of their body weight per day (Opuszynski 1972). Their gut is short for a herbivore, approximately 2.25 times their standard length, and they digest only about 50% of the plant material ingested (Hickling 1966), so they must consume large amounts of vegetation each day to maintain fast growth (Cross 1969).

Fears that grass carp might escape from areas stocked for vegetation control to form feral populations, since realized in the Mississippi River drainage (Guillory and Gasaway 1978), caused several states to ban the species from their waters. This led to a search for alternative forms as effective as the grass carp at weed control, but sterile. One area of the search, involving hybridization studies, has resulted in the recent production of hybrids between grass carp females and male bighead carp *Aristichthys nobilis*, a zooplanktivore native to the Amur River basin. Both parents have a diploid chromosome number of 48 and all of the hybrids were once thought to be triploid (Marian and Krasznai 1979) and presumably sterile (Beck et al. 1980). Recently, workers have discovered that this hybridization produces both diploid and triploid hybrids with chromosome numbers of 48 and 72, respectively (Magee and Philipp 1982; Beck and Biggers 1983). Even though the hybrids resemble the grass carp morphologically, it is yet to be demonstrated that they are as effective in controlling vegetation. In this paper we examine the food preferences of the hybrid and compare the feeding and growth of both forms at three temperatures.

Methods

We determined the relative preferences of the hybrids for three macrophytes—coontail *Ceratophyllum demersum*, southern naiad *Najas guadalupensis*, and water weed *Elodea nuttallii*—and a filamentous-algae complex—primarily *Mougeotia* sp., *Oedogonium* sp., and *Spirogyra* sp.—all of which are common in southern Illinois. Hybrids were 15–20 cm total length and 33–78 g. They were stocked in three, 208-liter glass aquaria operated as single-pass systems. The drain-pipe area of each aquarium was screened to prevent any loss of plant material. Water was supplied to each aquarium at rates varying from 0.4 to 0.6 liters/minute. In the first of three runs, six fish were placed in each aquarium with 35 g (wet weight) of each plant or complex. After six days, all uneaten vegetation was weighed to determine, by difference, approximate orders of preference. In the second run, 70 g (wet weight) of each of the two plants most highly preferred in the first run were offered to fish in each tank. In the third run, 70 g (wet weight) of each of the two least preferred plants were offered. Results of the three trials were collated to determine the order of preference.

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The effect of temperature on feeding rates and growth rate of grass carp and the hybrid was investigated in three aquaria maintained at 14, 22, and 30 C. These temperatures encompass the normal ranges found in midwestern lakes during spring, summer, and fall when vegetation can be a problem. Fish were brought to these temperatures at a rate of 1 C per day. Water was recycled through a biofilter system with a 1 liter/minute flush to maintain its quality. Four hybrids and four grass carp were placed in each aquarium; the two groups were separated by a screen across the center of each tank and the drain pipe area was screened to prevent any plants from being flushed out of the system. All fish were marked by a fin clip to allow examination of individual growth rates. *Najas guadalupensis,* the most highly preferred macrophyte in the food-preference study, was offered ad libitum in preweighed amounts every 2 days. On every second day throughout the trial, each tank was siphoned to remove accumulated excrement, and the remaining plant material was removed and weighed. Fish were weighed at the beginning and end of each trial; each trial lasted 20 days.

In the first trial, with "small" fish, hybrids that averaged 77 g (SD, 22) and grass carp that averaged 106 g (SD, 18) were used in 208-liter aquaria. In the second trial, with "medium-sized" fish, hybrids averaged 273 g (SD, 57), grass carp averaged 230 g (SD, 37), and the aquarium was 1,100 liters. Both of these trials were conducted at all three temperatures. The third trial, conducted only at 30 C, involved "large" hybrids that averaged 360 g (SD, 36) and "large" grass carp that averaged 518 g (SD, 45) in 1,100-liter aquaria.

Water-quality variables monitored throughout the entire study included total ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, temperature, dissolved oxygen, and pH. Water quality was acceptable during all phases of the study; total ammonia-nitrogen, nitrite-nitrogen, and nitrate-nitrogen never exceeded 0.5, 0.05 and 1.4 mg/liter, respectively. The lowest oxygen concentration (3.3 mg/liter) occurred for 1 day in the 30 C growth study with small fish. Temperatures in the aquaria used in the food-preference study increased gradually with each succeeding run as the ambient water supply warmed. Run 1 was conducted at 20 C, run 2 at 22 C, and run 3 at 23 C. The three experimental temperatures in the feeding-rate and growth study were maintained with minor fluctuations of 1 C or less.

Isozyme analyses (Magee and Philipp 1982) were run on 50% of the experimental fish by David Philipp of the Illinois Natural History Survey. All fish were triploid.

The mean weight of both forms were statistically compared by analysis of variance and subsequent LSMEANS procedure. An alpha-level ≤ 0.05 was used for all comparisons.

Results and Discussion

Food Preferences

Hybrids had a well-defined hierarchy of preferences among the plant foods offered: filamentous algae > *Najas guadalupensis* > *Elodea nuttallii* > *Ceratophyllum demersum* (Table 1). This order occurred whether foods were offered in groups of four or two categories, though more of the less-preferred plants were eaten when alternative choices were restricted. Avault et al. (1968) reported a similar hierarchy of food preferences for grass carp 31–41 cm, which preferred *Chara* sp. and *N. guadalupensis* over *C. demersum.* Other investigators have noted that

TABLE 1.—*Consumption of filamentous algae and macrophytes by 15–20-cm hybrids of grass carp ♀ × bighead carp ♂. Values are amounts eaten by six fish per aquarium over 6 days, expressed as percentages of initial wet food weights offered.*

Aquarium	Filamentous algae	*Najas guadalupensis*	*Elodea nuttallii*	*Ceratophyllum demersum*
Run 1: 35 g offered of each food[a]				
1	100	71	3	29
2	100	74	43	11
3	100	97	51	14
Mean	100	81	32	18
Run 2: 70 g offered of each food[b]				
1	100	73		
2	100	89		
3	100	100		
Mean	100	87		
Run 3: 70 g offered of each food				
1			33	17
2			71	14
3			93	51
Mean			66	27

[a] Filamentous algae were all consumed by day 6.
[b] Filamentous algae were all consumed by day 5.

TABLE 2.—*Comparative influences of fish size and temperature on growth and feeding efficiencies of grass carp and hybrids of grass carp ♀ × bighead carp ♂. Four grass carp and four hybrids per aquarium were fed* Najas guadalupensis *ad libitum for 20 days.*

Form	Starting weight (mean ± SD) g	Temperature C	Final weight (mean ± SD) g	20-day weight gain (mean ± SD) g/100 g[a]	Total food eaten by four fish g	Feeding efficiency per four fish (weight gained/weight eaten) %
			Small fish			
Grass carp	103 ± 18	14	115 ± 11	14 ± 6	2,726	1.72
	94 ± 13	22	111 ± 14	22 ± 6	3,576	1.90
	121 ± 11	30	164 ± 16	52 ± 18	6,870	2.46
Hybrid	73 ± 24	14	75 ± 25	2 ± 3	561	1.07
	89 ± 28	22	92 ± 33	3 ± 8	946	1.37
	69 ± 11	30	71 ± 12	4 ± 4	1,062	1.03
			Medium-sized fish			
Grass carp	202 ± 36	14	256 ± 45	26 ± 5	9,965	0.53
	238 ± 37	22	329 ± 46	39 ± 16	25,722	1.40
	250 ± 28	30	339 ± 63	35 ± 12	29,104	1.22
Hybrid	232 ± 60	14	276 ± 74	19 ± 1	4,929	3.69
	270 ± 37	22	307 ± 40	14 ± 8	15,507	0.95
	318 ± 45	30	306 ± 27	−1 ± 10	12,751	−0.38
			Large fish			
Grass carp	519 ± 45	30	681 ± 73	31 ± 3	52,043	1.24
Hybrid	360 ± 36	30	356 ± 56	−2 ± 6	13,457	−0.13

[a] g/100 g = (weight gained/initial weight of fish) × 100.

young grass carp often highly prefer filamentous algae (Buck et al. 1975; Ritenour 1976; Lewis 1978), but not *Ceratophyllum demersum* (Colle et al. 1978). Mitzner (1978) reported that grass carp did not utilize *C. demersum* until they reached 71 cm and 4,263 g.

Growth and Feeding Efficiencies

Growth (g/100 g), total food eaten, and feeding efficiency increased with temperature for both the small hybrid and the small grass carp; however, the only significant differences in growth occurred in small grass carp between 14 and 30 C and between 22 and 30 C (Table 2). No other significant differences in growth, as related to temperature, occurred in small fish of either form. Growth of medium-sized grass carp increased between 14 and 22 C but then decreased between 22 and 30 C; no differences were significant (Table 2). Feeding increased with temperature for both forms of medium-sized fish except for a slight decrease among hybrids at 30 C. Growth of medium-sized hybrids decreased with temperature; hybrids actually lost weight at 30 C. These decreases were significant between 30 C and both of the two lower temperatures. As could be expected, these decreases in growth of medium-sized hybrids are reflected in decreases in their feeding efficiencies.

The effect of size on growth rate of the hybrid and grass carp was also examined. At 14 and 22 C, the medium-sized hybrids grew significantly faster than the small hybrids; no significant differences occurred at 30 C (Table 2). The medium-sized and large grass carp held at 30 C grew significantly faster than the small grass carp held at 30 C, but there were no differences at 14 or 22 C.

Grass carp growth was significantly greater than that of the hybrid at all temperatures among all size groups except medium-sized fish at 14 C, where no difference was detected (Table 2). In all situations, grass carp consumed at least twice as much vegetation as did hybrids, except for the medium-sized hybrid held at 22 C. As one would expect from the preceding, grass carp also fed more efficiently than did hybrids (Table 2). This overall superiority of the grass carp is most evident among medium-sized and large fish held at 30 C; hybrids actually lost weight, while grass carp gained weight at considerable rates. Of the 8 hybrids in these two size groups, 6 lost weight and 2 gained weight. We believe these poor performances by the hybrid are real and not artificial, because both hybrids and grass carp were held in the same tank under identical conditions.

It has been postulated that the grass carp has a low feeding efficiency because of its short gut length (Cross 1969). The hybrids used in this study had a mean gut length of 2.61 (SD, 0.39) times the standard length, whereas the grass carp mean was 2.31 (SD, 0.20). Despite the longer gut, the feeding efficiency of the hybrid was less than that of the grass carp. The differences in efficiency may be due to other factors, such as less-developed pharyngeal teeth and a smaller gut diameter in the hybrid (Berry and Low 1970), or differences in digestive enzymes.

Evaluation of the Hybrid

Based on our laboratory feeding and growth studies, the effectiveness of the hybrid decreases significantly at 30 C, for the medium-sized and large fish tested. Even under more favorable temperatures, it will require at least twice as many hybrids as grass carp of the same size to obtain the same level of vegetation control. In pond studies conducted by Osborne (1982), feeding and growth rates of the hybrid were much lower than those of the grass carp. Thus, the hybrid appears to be a much less efficient herbivore than the grass carp and is not recommended for use as a weed-control agent.

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