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FOOD HABITS AND GROWTH OF SILVER AND BIGHEAD CARP IN CAGES AND PONDS

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ABSTRACT

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Analysis of intestinal contents of silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) showed that silver carp consumed primarily phytoplankton while bighead carp consumed large quantities of zooplankton and detritus in addition to phytoplankton. The size of particles filtered by the bighead carp was larger (17—3,000 μm) than that filtered by silver carp (8—100 μm). Artificial feed was readily consumed by bighead carp but not by silver carp. No growth difference was indicated for silver carp in fertilized ponds and ponds receiving artificial feed. Growth of bighead carp increased substantially with the addition of artificial feed. Silver carp grew more rapidly in cages than bighead carp.

INTRODUCTION

Exotic fish species have recently drawn much attention in the United States as management and culture species (Smitherman et al., 1978). The silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) were introduced into the United States from Taiwan in 1971 for the purpose of biofiltration of sewage lagoons (J. Malone, Lonoke, Ark., personal communication, 1975). Auburn University obtained stocks of the silver carp and bighead carp in 1974 to examine their potential in polyculture systems with existing U.S. culture species.

Objectives of this study of the silver and bighead carp were to determine:
(1) food habits in fertilized ponds and ponds receiving artificial feed;
(2) selectivity in feeding behavior;
(3) filtering capability and method of filtration;
(4) comparative growth in ponds receiving fertilizer and/or feed;
(5) comparative growth in ponds and cages.

MATERIALS AND METHODS

Silver and bighead carp fingerlings were stocked in two 0.04-ha and one 0.024-ha earthen ponds. Silver carp averaged 21.7 g at stocking; bighead carp averaged 13.2 g at stocking. Stocking density was 50 fish per pond for each species. Twenty-five fish of each species were stocked in the open pond and 25 fish in a single 1-m^3 floating cage. Ponds were limed at 1,150 kg/ha to increase alkalinity, and fertilized with 45 kg/ha (20—20—5 NPK) per application to maintain a phytoplankton bloom. Fish in one pond were fed the last 2 months of the study to determine acceptance of artificial feed by the two species. A water-stable ball, containing ground Purina Trout chow, carboxymethyl cellulose (5% of total ingredient weight), and water, was fed on a dry weight basis at 3% of body weight per day the first 30 days. Floating trout pellets were fed at the same rate the second 30 days. Fish in cages and in the open pond were fed.

The lengths and weights of silver and bighead carp in ponds and cages were determined monthly during a 159-day culture period. Subsamples of three silver and three bighead carp were taken monthly from each pond and cage for examination of intestinal contents. In addition, three silver and three bighead carp were removed for intestinal examination monthly from each of three 0.04-ha ponds stocked with 1,250 silver carp, 1,250 bighead carp and 25,000 channel catfish per hectare. These fish were intensively fed and the pond water aerated. Specimens removed for examination of intestinal contents were replaced by fish of similar size. Intestines were preserved in 10% formalin solution.

Initially, intestinal tracts of individual fish were examined. Separate 0.5-cc samples were taken from the fore-, mid-, and hind-intestine of each fish and diluted with 200 ml of water. Qualitative and quantitative observations were made on three, 1-ml samples from each dilution using a Sedgewick-Rafter counting cell and a compound microscope. Later, 1.0-cc samples from the fore-intestine of all three fish from the same treatment were combined for analysis. A total of 108 silver carp and 108 bighead carp were examined. Lengths of intestines were measured for comparison with total length of fish. Plankton and other filtered materials were measured to the nearest micrometer to determine filtering capabilities for silver and bighead carp.

Phytoplankton were identified to genus (Whitford and Schumacher, 1973). Zooplankton were identified to order or family (Pennak, 1953). Feed particles were included with detritus.

Three 1-l water samples were taken every 2 weeks from three stations in each pond at a depth of 50 cm from July through October. Subsamples were preserved with a 3.6% merthiolate solution. Qualitative and quantitative observations were made on three 1-ml samples from each concentrated sample.

Gills were removed from silver and bighead carp specimens to examine the filtering mechanism of the gill raker systems. Individual gill rakers from 20—25 cm fish were measured to the nearest micrometer and anatomy was noted.

RESULTS

Phytoplankton, zooplankton, and detritus found in silver and bighead carp intestines were as follows:

(A) Phytoplankton

(1) Bacillariophyceae — *Frustulia, Navicula, Nitzschia*
(2) Chlorophyceae — *Ankistrodesmus, Asterococcus, Closterium, Coelastrum, Dictyosphaerium, Dispora, Gloeocystis, Gonium, Microspora, Nephrocytium, Oocystis, Pediastrum, Scenedesmus, Selenastrum, Sphaerocystis, Staurastrum, Tetraedron, Ulothrix, Volvox*
(3) Cyanophyceae — *Anabaena, Chroococcus, Merismopedia, Oscillatoria, Polycystis, Spirulina*
(4) Dinophyceae — *Ceratium, Peridinium*
(5) Euglenophyceae — *Euglena, Phacus, Trachelomonas*

(B) Zooplankton

Amphipoda, Diptera (Chironomidae), Cladocera, Copepoda, Hydracarina (Hydrachnidae), Ostracoda, Rotifera

(C) Detritus

Feed, soil particles, unidentifiable particulate matter, and occasional macrophytic plant pieces, insect wings, and seed cases.

Genera of phytoplankton in silver and bighead carp intestines were similar, with *Coelastrum, Scenedesmus* (catfish ponds only), *Dictyosphaerium, Sphaerocystis,* and *Spirulina* the predominant genera. Phytoplankton genera in water samples, with the exception of a few genera occurring in trace quantities, were found in proportionate amounts in samples from intestines, indicating no selectivity for specific types of phytoplankton by either species. Lin (1969) and Manandhar (1977) also reported no selectivity for either species, although Chiang (1971) reported silver carp selectively fed on Cyanophyceae and Chlorophyceae. Seasonal variations in phytoplankton genera were reflected in intestinal samples. Few *Selenastrum* were found in the intestinal contents, however, despite its predominance in several of the plankton samples (Fig. 1). The absence of *Selenastrum* in the intestinal contents was probably reflective of its size, generally being less than 10 μm in diameter, which placed it at the bottom range of the indicated filtering capability of the silver carp, and below the indicated filtering capability of the bighead carp.

Phytoplankton identified in water samples differed only slightly from that found in intestines, and were as follows:

(1) Bacillariophyceae — *Frustulia, Nitzschia*
(2) Chlorophyceae — *Ankistrodesmus, Arthrodesmus, Asterococcus, Closterium, Coelastrum, Dictyosphaerium, Dispora, Eudorina, Gonium, Pediastrum, Scenedesmus, Selenastrum, Sphaerocystis, Staurastrum, Tetraedron, Volvox*
(3) Cyanophyceae — *Anabaena, Aphanocapsa, Spirulina*

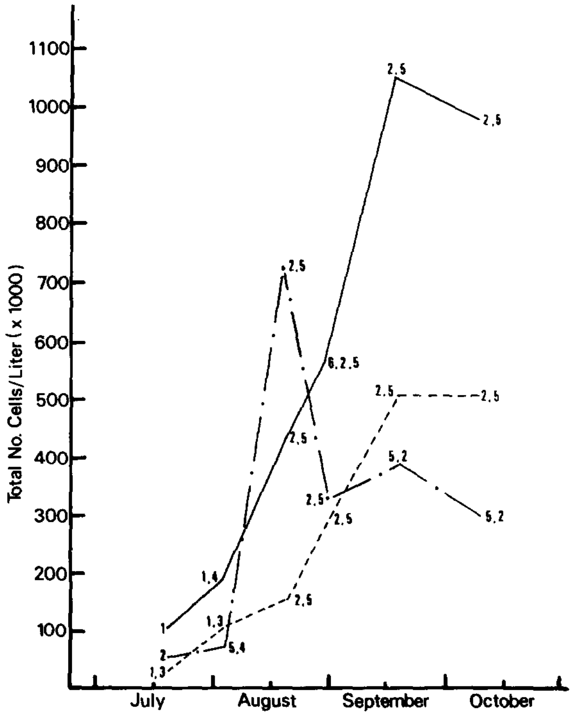

Fig.1. Phytoplankton densities and dominant genera in three inorganically fertilized ponds stocked with silver and bighead carp. Dominant genera are those which each comprised 25% or more of the total number of cells per liter of water. Key: 1 — *Selenastrum;* 2— *Coelastrum*; 3 — *Closterium*; 4 — *Sphaerocystis;* 5 — *Dictyosphaerium*; 6 — *Spirulina.*

(4) Dinophyceae — *Gymnodinium*
(5) Euglenophyceae — *Euglena, Trachelomonas*

Coelastrum, Dictyosphaerium, Spirulina, Selenastrum, Scenedesmus, Closterium, and *Sphaerocystis* were the predominant genera, respectively, in water samples. Phytoplankton predominance varied seasonally as well as between ponds, as did plankton density (Fig.1).

Combined intestinal analysis showed silver carp contents to be almost entirely phytoplankton, with zooplankton rarely present (Table I). Tang (1970) reported similar results, and classified silver carp as phyto- and micro-zooplankton feeders, with zooplankton at less than 7% of the total plankton organisms. Bighead carp, in contrast, had zooplankton present in their intestinal contents during all sampling periods (Table I). The diversity and quantity of zooplankton in the present study indicate the bighead carp is wide-ranging in its feeding behavior, with some active feeding taking place along the pond bottom in addition to the middle and upper layers of the water column. This is further substantiated by the difference in percent detritus

TABLE I

Intestinal contents of silver and bighead carp in fertilized ponds

Group	Intestinal contents (%)			
	Silver (pond)	Bighead (pond)	Silver (cage)	Bighead (cage)
Bacillariophyceae	2.4	0.6	2.1	2.3
Chlorophyceae	81.9	6.4	84.1	66.8
Cyanophyceae	0.4	0.1	0.5	0.3
Euglenophyceae	0.0	0.0	0.0	0.0
Dinophyceae	0.0	0.0	0.0	0.0
Zooplankton	0.0	23.6	0.0	5.3
Detritus	15.3	69.3	13.3	25.3
Total	100.0	100.0	100.0	100.0

between species and treatments (Table I). Percent intestinal detritus in bighead carp in fertilized ponds averaged 69.3%. This was 4.5 times greater than in silver carp in fertilized ponds and 2.9 times greater than in bighead carp caged in fertilized ponds, indicating much wider foraging behavior by bighead carp in ponds.

Particles filtered by bighead carp were considerably larger than those by silver carp. Bighead carp filtered phytoplankton, zooplankton, and detritus within a range of 17—3,000 μm. The majority of phytoplankton was 50—100 μm. Silver carp filtered both nanno- and net phytoplankton and detritus, with a particle size range of 8—100 μm. The majority of phytoplankton was 17—50 μm.

The gill raker structures of silver and bighead carp differ considerably, and reflect the filtering capabilities of the two species. The gill rakers of the bighead carp are shorter and thicker than those of the silver carp. In 22-cm fish, silver carp mean raker length was 7,225 μm and width was 34 μm, while in bighead carp these measurements were 3,230 μm and 85 μm, respectively. In the bighead carp, the gill rakers are closely set but separate from one another (Lin, 1969). In the silver carp, the gill rakers are covered by a netlike matrix of undetermined histological composition. This matrix binds the rakers together and may allow movement of smaller plankton through the matrix to the rakers, while preventing the passage and entrapment of larger plankton and particulate matter. This would explain the absence of large material in the silver carp intestinal contents. Wilamovski (1972) described this netlike matrix as modified gill rakers with pores not larger than 20 μm, through which food masses are washed by action of a suprabrachial organ. In this study plankton and detritus measuring 100 μm were found in the intestinal contents of silver carp, indicating there may be an additional procedure involved in the filtering mechanism other than that outlined by Wilamovski (1972).

The absence of *Selenastrum*, a dominant plankton in several of the water samples, also suggests additional size selectivity by the silver carp filtering mechanism. The size of *Selenastrum* (< 10 μm) should permit its passage through the net-like matrix covering the gill rakers. Rapid digestion of *Selenastrum* was considered as an explanation for its apparent absence in the intestine; however, as the time to change ingesta to excreta in silver carp is estimated to be 8—10 h (Chiang, 1971), at least a portion of any ingested *Selenastrum* should have been identifiable in the fore-intestine of silver carp examined. Further study appears necessary to fully understand the filtering mechanism of the silver carp.

Only bighead carp consumed the artificial feeds tested. Bighead carp were observed feeding on floating pellets at the pond surface, and bighead carp growth was 57% greater in the pond receiving supplemental feed than in ponds receiving fertilizer only. Bighead carp growth was 53% greater in the cage with feed than in cages without feed (Table II). There was an increase in bighead carp intestinal detritus (the category including feed particles) from 30% to 73% in the pond and from 15% to 35% in the cage which received feed. Silver carp were not observed feeding on pellets, nor was there a corresponding increase in detritus with the addition of feed. Hora and Pillay (1962), however, reported silver carp feed well on artificial foods when kept in ponds. In polyculture experiments at Auburn University, bighead carp slightly decreased channel catfish production, indicating direct competition for feed (Pretto, 1976). Silver carp in the same experiments showed a trend to increase the yield of catfish (Pretto, 1976).

Silver carp growth was similar in both fertilized ponds and ponds receiving feed (Table II). Mean growth for silver carp was approximately 2.7 g/day for 159 days. Bighead carp growth was similar in all ponds until supplemental feeding was initiated at which time growth increased in the pond receiving

TABLE II

Growth of silver and bighead carp in ponds and cages with fertilization and supplementary feed during a 159-day culture period

Species	Treatment	Mean harvest wt. (g)	Growth/day (g)
Silver carp	pond — fertilized	439.1	2.6
Silver carp	pond — fertilized & fed	458.5	2.7
Bighead carp	pond — fertilized	371.3	2.3
Bighead carp	pond — fertilized & fed	582.0	3.6
Silver carp	cage — fertilized	270.5	1.6
Silver carp	cage — fertilized & fed	258.0	1.5
Bighead carp	cage — fertilized	133.3	0.8
Bighead carp	cage — fertilized & fed	203.0	1.2

TABLE III

Growth of supplementally-fed silver and bighead carp in monoculture and in polyculture with channel catfish

Species	Treatment	Mean harvest wt. (g)	No. days	Growth/day (g)
Silver carp	monoculture	458.5	159	2.7
Silver carp	polyculture	417.7[1]	170	2.4
Bighead carp	monoculture	582.0	159	3.7
Bighead carp	polyculture	524.2[1]	170	3.0

[1] Represents mean weight of carp from three 0.04-ha ponds stocked with silver and bighead carp and channel catfish. All carp (2,500/ha) were free in the pond with channel catfish at 25,000/ha.

feed. Mean growth for bighead carp in fertilized ponds was 2.3 g/day, compared to 3.6 g/day in the pond receiving feed (Table II). Maximum growth of silver and bighead carp in ponds with intensively fed catfish was similar to that obtained in monoculture (Table III).

Silver and bighead carp growth was considerably less in cages than in ponds (Table II). Mean growth for silver carp in cages was approximately 1.6 g/day, compared to 2.7 g/day in ponds. Bighead carp growth in cages was 0.8 g/day, compared to 2.3 g/day in ponds. Greater growth of silver carp over bighead carp in cages is probably indicative of its superior filtering capability. No growth difference was noted between supplementary fed and unfed silver carp in cages. Bighead carp growth was 53% greater in the cage with supplemental feed than in cages without feed.

Differences in phytoplankton density between ponds did not affect silver carp growth. Manandhar (1977) also reported no effect on silver carp growth rates as a result of increased phytoplankton volumes in ponds.

Intestinal length in comparison to total fish length was greater in silver carp than in bighead carp. Silver carp intestinal length was 3.5—7.3 times greater than total length, with a mean of 5.0. Bighead carp intestinal length was 2.0—4.5 times greater than total length, with a mean of 3.3. This is the expected result, as fishes feeding on plant material generally have greater gut length than those feeding on animal matter (Nikolsky, 1963).

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