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Daily Food Consumption and Feeding Rhythm of Silver Carp (*Hypophthalmichthys molitrix*) During Fry to Fingerling Period

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ABSTRACT

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Daily food consumption and feeding rhythm of silver carp (*Hypophthalmichthys molitrix*) from fry to fingerling (6.6-195 mm in total length) were measured from June 1985 to August 1986 using a method of intestine filling index. Absolute food consumption (expressed as wet weight of food consumed per fish each day) was positively related with the body weight of silver carp, and relative food consumption (expressed as wet food consumed as percentage of fish body weight) decreased with increases in body length of the fish. The relative food consumption of silver carp averaging 6.6-8.6 mm in total length was $139.2 \pm 6.6\%$; as the fish grew, relative food consumption reduced to $30.7 \pm 3.3\%$. However, when total length reached 21.7-26.0 mm, relative food consumption increased to $63.2 \pm 5.0\%$ ($P < 0.05$), but decreased again to $16.5 \pm 1.2\%$ for fish 132-195 mm in total length. The variation in food consumption was due to a change in feeding habits from zooplankton to phytoplankton and the difference in nutritive contents of the plankton consumed by silver carp. An obvious daily feeding rhythm was observed. The fish did not feed from 22.00 h to 04.00 h, but from 09.00 h to 11.00 h and 17.00 h to 21.00 h the fish fed actively. The difference in intestinal filling indices between the feeding peak and low feeding level became less and less as the fish grew. The reason for this might be improvement in digestion.

INTRODUCTION

Food consumption and feeding rhythm of silver carp (*Hypophthalmichthys molitrix*), bighead (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idellus*) have been investigated by Ne and Jiang (1954), Huang et al. (1964), Chang (1966), Li et al. (1980) and De Silva and Weerakoon (1981). They found that silver carp fingerlings had an obvious feeding rhythm with active feeding during the day and cessation of feeding from midnight to dawn. The above authors also reported that the relative daily food consumption decreased with increase in size. These studies dealt with specific developmental stages, and the results were obtained at relatively long intervals (4 h). There have been no publications delineating the sequence of changes in food consumption, feeding intensity and diurnal rhythm of silver carp from fry to fingerling. In 1985 and 1986 we measured food consumption and daily feeding rhythm of silver carp varying from 6.6 mm to 195 mm in total length.

MATERIALS AND METHODS

In June 1985 and 1986 test fish of 6.2 ± 0.2 and 6.2 ± 0.3 mm in total length, respectively, were stocked into fertilized ponds varying in area from 600 to 1600 m^2 and a depth of 0.9–1.4 m at a stocking density of 1.5–1.8 million fish/ha. Fish of 6.6–30.0 mm in total length were directly sampled from the test ponds. Ten fish of 31–195 mm were stocked in June 1985 and 1986 into 0.5 m $\times$ 0.5 m $\times$ 1.0 m cages placed 8–10 m apart in the test ponds; fish were sampled from the cages until August.

During the experiment, water temperature varied from 18 to 23°C for the fish of 6.2 mm, and from 17 to 29°C for the fish of 31–195 mm. Dissolved oxygen ranged from 3.0 mg/l in the morning to 15.3 mg/l in the afternoon. The biomass of phytoplankton fluctuated between 20.36 and 86.04 mg/l from June to August, dominant species being *Euglena* and *Navicula*. Zooplankton biomass varied from 5.61 to 48.30 mg/l, with rotifers (*Brachionus angularis* and *B. calyciflorus*) and cyclop nauplii the dominant forms.

Daily food consumption of silver carp was measured according to the index of intestinal filling (Li et al., 1980). Ten fish were sampled every 2 h day and night every 6 days from 4 June to 5 August. The specimens were immediately fixed in 5% formalin solution. For silver carp fry of 6.6–18.8 mm total length, the intestinal content was measured by counting the numbers and measuring zooplankton consumed by the fish under a microscope (He, 1985). After recording intestinal content, the wet weight of rotifers was calculated by the Vinberg equation used by He (1985), and the wet weights of cladocerans and copepods were calculated by Balushia–Vinberg's equation (He, 1985). For silver carp fingerlings varying from 19.0 mm to 195 mm in total length, the intestinal content was weighed on a balance to the nearest milligram.

Intestinal evacuation was determined by the amount of intestinal content from fish of different sizes. The fish sampled from the ponds or from the cages were kept in troughs containing tap water and exposed to sunlight. The intestinal contents of three fish were recorded each 0.5–1.0 h by dissecting the intestines. For fish of 6.6–20.0 mm, intestinal evacuation was the number of hours for the intestine to empty. For fish larger than 21 mm intestinal evacuation was the number of hours for 60–70% of the food to pass from the intestine, because larger silver carp begin to feed before all food has passed from the intestine. Feeding selectivity of silver carp for different foods was calculated by Ivlev's (1955) equation, in which $E=(r-p)/(r+p)$, where E=Ivlev's selectivity index; r=occurrence of a specific food item as percentage of the total food ingested; p=percent occurrence of the specific food item in the environment.

The amount of food in the intestine was calculated as an intestinal filling rate $(K)=100$ (weight of intestinal content of fish in sample)/wet body weight of fish in sample. Daily mean K was calculated by adding the 12 K values and then dividing the total by 12. Daily food consumption was estimated as DFC=daily mean $K\times(24)/$(number of hours for intestine to empty).

Adjacent pairs of data were analyzed for significant differences by Student's t test (Haber and Runyon, 1977). We accepted $P<0.05$ as the level of statistical significance.

RESULTS AND DISCUSSION

The selectivity index of silver carp under 18.8 mm in total length for Cladocera and Copepoda was between −0.45 and −1.0, whereas the selectivity index for rotifers and nauplii was 0.28–0.90 (Table 1). This indicated that silver carp at this size avoided cladocerans and copepods, and actively concentrated on rotifers and nauplii. When total length was greater than 18.8 mm, feeding selectivity was reversed. The intestinal content of fish greater than 26.0 mm was almost all phytoplankton. Our results support the suggestion that ontogenetic feeding changes of silver carp coincide with development of the filtering apparatus of filter-feeders (Lei et al., 1981). However, selectivity of fish varying from 6.6 to 8.6 mm for nauplii ($E=0.90\pm0.07$) was higher than for rotifers ($E=0.28$–0.37) ($P<0.05$). Shirota (1970) suggested that the size

TABLE 1

Selectivity of different size silver carp for various forms of zooplankton. Values are expressed as the mean ± SE of determinations from 10-15 fish. Asterisks denote that adjacent mean values have a significant difference (Student's t test; $P<0.05$)

Fish size		Zooplankton			
Total length (mm)	Body wt. (mg)	Rotifer	Nauplius	Cladocera	Copepod
6.6-8.6	1.6-3.4	0.37 ± 0.05*	0.90 ± 0.07	−0.46 ± 0.04	−1.0 ± 0.02
8.5-13.3	7.8-20.6	0.28 ± 0.04*	-	−0.67 ± 0.08	-
14.5-18.8	22.9-63.0	0.42 ± 0.08*	-	−0.45 ± 0.04	-

of food particles consumed depends on mouth size, and reported that the mouth width of a triangle of 45 degrees between the upper and lower jaw was the optimal particle size. In our experiment, the rotifers found in the test ponds were small, while the size of nauplii was optimal for food particles. Therefore, silver carp expressed a high selection for nauplii.

Absolute daily food consumption (expressed as wet weight of food consumed per fish per day) of fry weighing 1.6–3.4 mg was 2.2–4.7 mg (Table 2). When body weight reached 22.9–63.0 mg, the absolute daily food consumption increased to 7.0–19.3 mg, and for fish weighing 18.1–39.9 g, the absolute food consumption was only as high as 5.34–8.76 g. The relative daily food consumption (expressed as percent body weight) decreased with increase in body weight and length of the fish. Table 2 illustrates that the relative food consumption of fish weighing 1.6–3.4 mg was as high as 139.2 ± 6.6%, whereas for fish of 63.0 mg the relative daily food consumption declined to 30.7 ± 3.3%. This reflects the high metabolic rate of fry compared to fingerlings. However, compared with smaller fish, the relative daily food consumption of fish weighing between 69.4 and 165.9 mg did not decrease but increased from 30.7 ± 3.3% to 63.2 ± 5.0% ($P < 0.05$) (Table 2). There is more carbohydrate and less protein and lipid in phytoplankton than in zooplankton except for certain species of blue-green algae. For example, there is 46% protein in *Daphnia pulex*, whereas diatoms contain only 23% protein (He, 1985). Chen et al. (1985) reported that relative daily food consumptions of silver carp weighing 16.39 ± 1.65 g and bighead weighing 17.08 ± 2.27 g were 12.24% and 11.37%, respectively. In our experiment, the relative food consumption of silver carp weighing 18.3–39.9 g and feeding on phytoplankton was 16.5 ± 1.2%, which is 34.8% higher than for carp feeding on *Daphnia* (Chen et al., 1985). This indicates that when silver carp change their diet from zooplankton to phytoplankton at a length of 30 mm

TABLE 2

Daily food consumption of different size silver carp. Values are expressed as the means ± SE of determinations from 15–20 fish. Asterisks denote a significant difference between two adjacent mean values (Student's t test; $P < 0.05$)

Size		Daily food consumption	
Total length (mm)	Body wt. (mg)	Absolute (mg/fish)	Relative (%)
6.6–6.8	1.6–3.4	2.2–4.7	139.2 ± 6.6
8.5–13.3	7.8–20.6	3.5–4.6	58.8 ± 2.3*
14.5–18.8	22.9–63.0	7.0–19.3	30.7 ± 3.3*
21.7–26.0	69.4–165.9	43.9–104.9	63.2 ± 5.0*
27.0–35.9	57.3–553.6	2986 –6580	48.9 ± 4.8*
132 –195	18 100 –39 900	5340 –8760	16.5 ± 1.2*

(Lei et al., 1981), they need more nutrition and energy, but the food consumed contains less nutrition and energy. The fish obtain their nutrition and energy by increasing food consumption, which is the reason why the relative food consumption increased again.

Table 3 shows that there was a diurnal rhythm of feeding for silver carp. The fish essentially ceased feeding during the darkness from 23.00 h to 04.00 h. The intensity of food consumption was higher both at 09.00–11.00 h and at 17.00–21.00 h than at 05.00–08.00 h. The highest level of daily food consumption was recorded at about 11.00 and 17.00 h. These results were identical with the observations reported by Huang et al. (1964), Chang (1966), and Li et al. (1980) for silver carp and for tilapia (*Tilapia nilotica*) observed by Moriarty and Moriarty (1973). Kryuchukov et al. (1984) found that the mean hourly values of diel locomotor activity in young mirror carp (*Cyprinus carpio*) aged 1–12 months had one or two peaks of activity (18.00–20.00 h and/or 08.00–10.00 h), the lowest hourly values of activity were recorded at 02.00–04.00 h. A three-peak rhythm of daily oxygen consumption was recorded in juvenile grey mullet (*Liza saliens*), gold mullet (*L. aurata*) and striped mullet (*Mugil cephalus*), the largest peak being at 14.00–20.00 h, and the morning (06.00 h) and night (24.00 h) peaks being small (Shekk, 1986). Shekk suggested that the increase in oxygen consumption and activity of the mullets during the day is associated with the period of active feeding and during the night with migration. Huang et al. (1964) and Chang (1966) explained that the reason fish cease feeding during the period of 24.00–05.00 h was the low dissolved oxygen and low water temperature at that time. In our experiments, the lowest dissolved oxygen re-

TABLE 3

Feeding rhythm of silver carp fry and fingerlings. Values are expressed as the mean ± SE of determinations of intestinal filling indices from 10 fish. Asterisks denote two adjacent mean values significantly different (Student's t test; $P<0.05$)

Time	Mean intestinal filling index[a]		
	Total length (mm)		
	6.6–13.3	14.5–26.0	33.0–195
05.00	0.8 ± 0.2	1.1 ± 0.2	2.0 ± 0.2
08.00	4.2 ± 0.3*	4.1 ± 0.4*	2.7 ± 0.4*
11.00	19.9 ± 1.4*	6.0 ± 0.5*	3.4 ± 0.4*
14.00	18.2 ± 1.1*	3.8 ± 0.3*	2.2 ± 0.2*
17.00	8.3 ± 0.5*	9.1 ± 0.6*	2.2 ± 0.2*
20.00	12.4 ± 1.0*	5.6 ± 0.3*	2.7 ± 0.3*
23.00	1.2 ± 0.2*	3.8 ± 0.3*	2.1 ± 0.2*
02.00	1.2 ± 0.2	1.8 ± 0.2*	1.9 ± 0.1

[a]Intestinal filling index = 100 × (wet weight gut contents/wet body weight).

corded was 3 mg/l and the lowest water temperature was 17°C at 03.00–05.00 h; Hainsworth (1981) observed that rainbow trout (*Oncorhynchus mykiss*) seek optimal temperatures for feeding which could reduce energy expenditures. De Silva et al. (1986) also found that under constant oxygen concentration the daily rhythm of oxygen consumption by *Oreochromis nilotica* fry is identical with that of the feeding period. This indicates that feeding periodicity reflects a physiological rhythm evolved as an adaptation to optimally utilize natural food resources.

The intestinal filling index of silver carp varied from 3.4 to 19.9 during the feeding peak (11.00 h) (Table 3). There is a tendency for the difference between the highest and lowest indices during day and night to become less and less as the fish grow. The reason for this could be explained by the fact that while the fish grow, and the ability to digest food develops, the digestive tract becomes longer, and the number of hours for the intestine to empty increases. When the intestinal content was measured every 2–3 h during day and night, the filling index would be high without intestinal evacuation. The other reason is that the relative daily food consumption decreased with fish growth. Hence, only intensity of feeding can be determined by the index of intestinal filling.

Charles et al. (1984) reported that the highest weight gain and food conversion ratio were recorded in common carp (*Cyprinus carpio*) fry with feeding twice a day (08.00 and 16.00 h). These times corresponded with feeding physiologically during peak times, instead of feeding arbitrarily six times a day. In production of silver carp and fingerlings in China, it is a common practice that the fingerlings are fed twice a day at about 09.00–10.00 h and 14.00–15.00 h. We suggest that changing the second feeding time to 16.00–17.00 h might be more attuned to the natural feeding rhythm and result in more efficient growth.

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