The Open Access Israeli Journal of Aquaculture – Bamidgeh

As from **January 2010** The Israeli Journal of Aquaculture - Bamidgeh (IJA) will be published exclusively as **an on-line Open Access (OA)** quarterly accessible by all AquacultureHub (http://www.aquaculturehub.org) members and registered individuals and institutions. Please visit our website (http://siamb.org.il) for free registration form, further information and instructions.

This transformation from a subscription printed version to an on-line OA journal, aims at supporting the concept that scientific peer-reviewed publications should be made available to all, including those with limited resources. The OA IJA does not enforce author or subscription fees and will endeavor to obtain alternative sources of income to support this policy for as long as possible.

Published under auspices of
The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB),
University of Hawaii at Manoa Library
and
University of Hawaii Aquaculture Program in association with
AquacultureHub
http://www.aquaculturehub.org

ISSN 0792 - 156X

PUBLISHER:
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL
Phone: + 972 52 3965809
http://siamb.org.il

MANAGEMENT INDUCED CHANGES IN FOOD SELECTION, GROWTH AND SURVIVAL OF KOI CARP, *CYPRINUS CARPIO* VAR. *KOI* L., IN TROPICAL PONDS

Prithwiraj Jha and Sudip Barat*

Aquaculture and Limnology Laboratory, Department of Zoology, University of North Bengal, District Darjeeling, West Bengal 734 430, India

(Received 26.12.04, Accepted 12.3.05)

Key words: *Cyprinus carpio*, enriched ponds, food selection, larvae, plankton

Abstract

The effects of different management regimes on the feeding habits and food selection of koi carp (*Cyprinus carpio* var. *koi* L.) larvae were examined. Weight gain, fish deformities, and survival were compared in an 11-week growth trial conducted in tropical ponds maintained according to four culture regimes: (1) live food system; (2) poultry manure treated system; (3) cow dung treated system; and (4) a control. The Ivlev's Electivity Index showed that koi larvae avoided phytoplankton and preferred cladocerans, an important source of natural food in all the regimes. In the poultry and cow manured ponds, the larvae were negatively elective towards copepods although they were more abundant than cladocerans. Weight gain and survival was significantly higher in the live-feed system ($p<0.05$) than in the other systems. Fish deformities were significantly higher ($p<0.05$) in the control.

Introduction

One of the bottlenecks in the ornamental fish culture industry in India is the large-scale loss of fish during the larvae and postlarvae periods. To explain differing survival rates, early marine studies focused on the feeding behavior of young larvae (Hjort, 1914). Even in modern aquaculture, food is considered the most powerful variable affecting growth and metabolism (Kinne, 1962; Beamish and Dickie, 1967; Miller et al., 1988; Bunnell et al., 2003). Natural food is indispensable in the early life of fish (Crowder et al., 1987; Hart and Werner,

* Corresponding author. E-mail: sudipbarat@rediffmail.com

1987; Rottmann et al., 1991; Adeyemo et al., 1994; Welker et al., 1994; Al-Harbi and Siddiqui, 2001). Management strategies of fish husbandry are likely to influence species composition and abundance of plankton in the environment (Diana et al., 1991; Milstein et al., 1995; Garg and Bhatnagar, 1996; Akpan and Okafor, 1997; Jakubas, 2002; Mischke and Zimba, 2004) which could, in turn, affect the feeding habits, growth, and survival of the target fish species.

Two types of plankton feeding behavior are particulate feeding and filter feeding. In nature, switching from particulate to filter feeding behavior is a function of factors such as the density and size of the prey (Lazzaro, 1987; Dewan et al., 1991; Ushakumari and Aravindan, 1992; Xie, 1999; Serajuddin, 2000). Some plankton pass undigested through the gut of planktivorous fishes. In this case, since the fish expends energy to capture prey but receives no energy from consuming it, the fish may recognize and reject such undesirable organisms. Ivlev (1961) and Vinyard (1967), respectively, reported on slightly negative electivity towards ostracods by bleak, *Alburnus alburnus* L., and bluegill, *Lepomis macrochirus* Raf.

The koi carp, *Cyprinus carpio* var. *koi* L., is a popular ornamental fish. There are several reports on the husbandry of this fish (Feldlite and Milstein, 1999; Asano et al., 2003). However, to our knowledge, there have been no studies of the feeding habits and food preferences of the koi in Indian conditions. The objective of the present study was to investigate the food selection, growth, and survival of koi larvae reared under different management regimes in tropical ponds.

Materials and Methods

Study animals. Koi carp (*Cyprinus carpio* var. *koi* L.) larvae (0.13±0.015 g) from mixed commercial production by 40 pairs of *asagi*, *bekko*, and *showa* koi were obtained from a local fish farm (Rainbow Ornamentals, Jalpaiguri, India), and divided into two batches after a one-week acclimatization period.

Experimental design. The first batch was reared in 12 earthen ponds for 11 weeks (March 3-May 19, 2004) and used for the growth and survival studies. Each pond (9.14 x 6.10 x 1.07 m) had a capacity of 59,600 l. Larvae were stocked at the optimum density of 0.3 fish/l (Jha and Barat, in press). Three ponds were allotted to each of four management regimes: (a) live food ponds, into which about 1000 l of zooplankton water was transferred every day from plankton culture ponds. The plankton ponds were fertilized with 0.26 kg poultry manure/m^3 at the beginning of culture and every 10 days thereafter (Jha et al., in press); (b) poultry manure ponds, where poultry excreta was added to the koi larvae ponds at the same dose as above; (c) cow dung ponds, where cow dung was applied to the koi ponds at the above dose; and (d) control ponds, in which a commercial pelleted feed (Tokyu Corp., Japan) containing 32% crude protein was used.

Constant water levels were maintained in the culture ponds by supplying ground water to compensate for loss due to evaporation. In the live food treatment, about 1000 l of water was discharged every day during the introduction of the plankton water. A plankton cloth was tied over the outflow water pipe to prevent any loss of zooplankton during this process.

The second batch was used to study food selection. A 10-cm layer of soil was placed on the bottom of six 2000-l outdoor concrete tanks exposed to direct sunlight which were then filled with control pond water. The tanks were fertilized with 0.26 kg poultry manure/m^3 two weeks prior to stocking the carp fry and once every 10 days thereafter (Jha et al., in press). The koi were stocked and maintained at a density of 0.3 fish/l. Forty-eight fish were randomly removed at weekly intervals. Each fry was placed in a plastic container (5 l capacity) and starved for 48 h for gastric evacuation under laboratory conditions. Four containers, each containing one fry, were randomly placed on the bottom of different areas of each of the above twelve ponds (three for each management regime). The containers were covered with a net to prevent fish escape but allow free movement of the plankton between the container and the surrounding pond water. Hence, the containers represented the management regime of the pond in which they were placed in terms of water quality and plankton diversity. After 12 h, the fish were removed from the containers and sacrificed for examination of food selection and food consumption.

Data collection. Consumed plankton were identified and counted by analyzing the guts of koi in the second batch. Routine procedures were followed for gut analysis (Jhingran et al., 1988). Average values from the 12 containers used for each regime were used for further calculations. The extent of prey selection was determined using the formula of Ivlev (1961): $E = (r_1 - p_1)/(r_1 + p_1)$, where E is the electivity value, r_1 is the relative quantity of any ingredient in the gut expressed as a percent, and p_1 is the relative quantity of the same ingredient in the food complex, also expressed as a percent. Application of this formula results in a range of values from +1.0 indicating a very high degree of selection to -1.0 for complete avoidance. A value of 0 indicates that the feed is present in the diet in the same proportion as it is found in the environment, viz. a complete lack of selection.

Water samples were collected from the ponds at weekly intervals and analyzed according to methods described by APHA (1998). pH was measured *in situ* using a portable pH meter (Hanna Instruments, Rua do Pindelo, Portugal). Temperature was measured with a centigrade thermometer. Samples of plankton were collected with a plankton net made of standard bolting silk cloth (no. 21 with 77 mesh/cm^2) twice a week. Plankton samples were concentrated to 20 ml and preserved in 4% formalin. Plankton in a 1-ml concentration were counted under a stereoscopic microscope using the Sedgwick Rafter Counting Cell.

For growth studies, 1000 fish were randomly collected from each pond and individually weighed to the nearest 0.001 g at the beginning of the experiment and at harvest and the number and percent of fish with deformities were recorded. Dead fish were removed daily, they were not replaced during the course of study, and differences between the number of fish stocked and the number of fish at harvest were used to calculate survival. Final survival and percent of deformities were normalized using angular transformation (Sokal and Rohlf, 1969). The specific growth rate (%/day) for each treatment was calculated using the formula of Ricker (1975).

Statistical analysis. Analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference Test were used to determine significant differences between groups with respect to water quality, fish growth and survival, and number of deformed individuals.

Results

The compositions of planktonic food organisms in the environment and gut contents are presented in Table 1. Cladocerans were in higher abundance in the diet (82.14%) and environment (63.89%) than copepods (17.85% and 29.69%, respectively) in the live food treatment. Cladocerans were higher in the live food treatment than in the other treatments. In the cow dung treatment, cladocerans were more abundant in the fish gut (44.71%) than copepods (40.12%). *Moina* was the most dominant cladoceran in all the treatments, ranging in the environment from 5% in the control to 27.95% in the live food treatment and in the gut from 6.34% in the control to 31.81% in the live food treatment.

Copepods were more abundant in the control and manured ponds, ranging from 48.71% in the cow dung treatment to 61.33% in the control. *Cyclops* was the most dominant copepod in all the treatments. The average number of plankton per liter was highest in the live food treatment, followed by the poultry manure, cow dung, and control treatments, in that order ($p<0.05$; Fig. 1).

The larvae preferred cladocerans in all the treatments and were generally negative towards copepods except in the control where the electivity index was insignificant (0.005) and indicated an absence of any food selection. Electivity of rotifers was negative in all treatments with values ranging from -0.181 in the poultry manure treatment to -1.0 in the live food treatment. Likewise for phytoplankton

Table 1. Percent plankton in the gut of koi carp larvae and in experimental ponds, and Ivlev's Electivity Index*.

	Live food			*Poultry manure*			*Cow dung*			*Control*		
	% in gut	*% in environment*	*Ivlev Index*	*% in gut*	*% in environment*	*Ivlev Index*	*% in gut*	*% in environment*	*Ivlev Index*	*% in gut*	*% in environment*	*Ivlev Index*
Daphnia	22.25	14.72	0.204	12.72	7.36	0.267	14.08	7.31	0.316	4.94	3.06	0.235
Moina	31.81	27.95	0.065	18.13	11.69	0.216	18.24	11.93	0.209	6.34	5.00	0.118
Ceriodaphnia	25.26	19.61	0.126	10.15	7.01	0.183	10.52	7.75	0.152	4.28	3.62	0.084
Bosmina	2.91	1.59	0.293	1.28	1.32	-0.015	1.86	1.89	-0.008	4.51	3.03	0.196
Cladocera	**82.14**	**63.89**	**0.125**	**42.29**	**27.41**	**0.213**	**44.71**	**28.90**	**0.215**	**20.08**	**14.73**	**0.154**
Cyclops	11.89	16.67	-0.167	21.62	24.84	-0.069	18.78	23.49	-0.111	32.26	31.80	0.007
Diaptomus	-	0.90	-1.0	6.90	7.63	-0.050	4.19	6.48	-0.215	11.56	11.49	0.003
Nauplii	5.96	12.11	-0.340	17.59	18.84	-0.034	17.14	18.72	-0.044	18.19	17.93	0.007
Copepoda	**17.85**	**29.69**	**-0.249**	**46.12**	**51.32**	**-0.053**	**40.12**	**48.71**	**-0.097**	**62.02**	**61.33**	**0.005**
Brachionus	-	1.60	-1.0	3.51	4.87	-0.162	2.29	4.69	-0.344	3.92	5.04	-0.125
Keratella	-	0.67	-1.0	2.63	3.97	-0.203	0.87	3.75	-0.623	2.19	4.16	-0.310
Rotifera	**-**	**2.29**	**-1.0**	**6.14**	**8.85**	**-0.181**	**3.16**	**8.44**	**-0.455**	**6.12**	**9.21**	**-0.201**
Chlorella	-	0.81	-1.0	0.59	2.25	-0.585	1.82	2.63	-0.182	2.51	3.76	-0.199
Navicula	-	1.91	-1.0	2.32	4.75	-0.344	4.92	5.47	-0.053	4.28	5.14	-0.091
Spirogyra	-	0.63	-1.0	1.02	1.76	-0.266	1.60	1.71	-0.033	2.05	2.65	-0.128
Scenedesmus	-	0.04	-1.0	-	0.25	-1.0	-	0.46	-1.0	-	0.30	-1.0
Phacus	-	0.58	-1.0	1.50	3.03	-0.338	3.65	3.18	0.069	2.93	2.03	0.181
Synedra	-	0.12	-1.0	-	0.33	-1.0	-	0.46	-1.0	-	0.82	-1.0
Phytoplankton	**-**	**4.12**	**-1.0**	**5.44**	**12.42**	**-0.391**	**12.00**	**13.94**	**-0.075**	**11.77**	**14.73**	**-0.112**

* Electivity index = $(r_1 - p_1)/(r_1 + p_1)$, where r_1 is the relative quantity of the ingredient in the gut expressed as a percent, and p_1 is the relative quantity of the same ingredient in the food complex, also expressed as a percent.

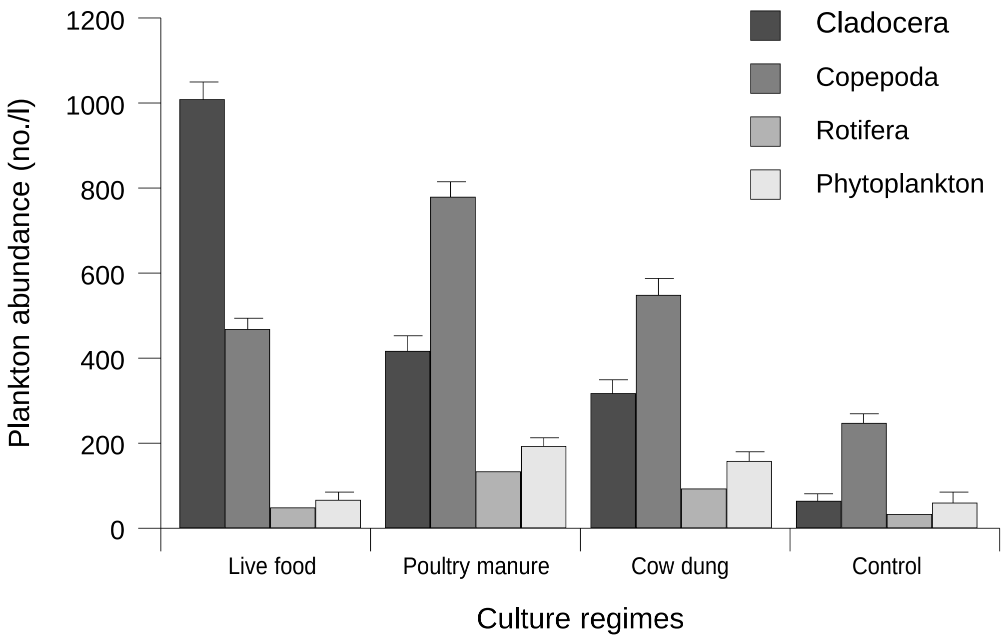

Fig. 1. Average number of plankton per liter.

which ranged from -0.075 in the cow dung ponds to -1.0 in the live food ponds.

Water temperature ranged 27-36°C with no differences between treatments at any time. pH and dissolved oxygen were significantly higher in the live food treatment than in the manured treatments (Table 2). Average specific conductivity and nitrite-N were significantly higher in the poultry ponds than in the others. Total alkalinity, here referring to bicarbonate alkalinity as carbonate, was absent in all treatments. Alkalinity, BOD, phosphate-P, ammonium-N, and nitrate-N were significantly higher in the manured treatments than in the live food and control treatments.

At harvest, the highest weight gain and specific growth rate were obtained in the live food treatment (Table 3). The number of deformed carp was highest in the control. Survival significantly differed among treatments, ranging 70.60-96.16%.

Discussion

Electivity indices ranging from -0.3 to +0.3 are generally considered insignificantly different from zero, and thus indicate non-selective feeding (Lazzaro, 1987). According to this interpretation, the koi larvae in our experiment did not show any significant food selectivity towards most planktonic organisms. Analyzed by plankton types, a strong rejection (below -0.3) was observed only towards phytoplankton in the live food and poultry manure treatments and towards rotifers in the live food and cow dung treatments. There were no incidences of strong selection (above +0.3). Analyzed by individual plankton, there was only one incidence of strong positive selection (towards *Daphnia* in the cow dung treatment).

Xie and Takamura (1996) and Serajuddin (2000), however, defined electivity values above +0.01 as positive and below -0.01 as negative, reducing the non-selective feeding

Table 2. Water quality parameters (means of 12 samples collected weekly for 11 weeks±SE).

	Treatment			
Parameter	*Live food*	*Poultry manure*	*Cow dung*	*Control*
pH	7.42±0.11 [a]	6.67±0.13 [b]	6.03±0.15 [c]	7.19±0.09 [ab]
Dissolved oxygen (mg/l)	7.32±0.10 [a]	5.19±0.23 [b]	5.67±0.18 [b]	6.97±0.13 [a]
BOD (mg/l)	1.67±0.06 [c]	2.61± 0.14 [a]	2.18±0.10 [ab]	1.82±0.08 [bc]
Free CO_2 (mg/l)	2.57±0.10 [c]	3.47±0.12 [a]	3.18±0.16 [ab]	2.84±0.13 [bc]
Total alkalinity (mg/l)	31.75±1.18 [b]	79.92±5.14 [a]	70.25±4.28 [a]	34.42±1.86 [b]
PO_4-P (mg/l)	0.23±0.021 [b]	0.53±0.059 [a]	0.45±0.039 [a]	0.28±0.024 [b]
NH_4-N (mg/l)	0.151±0.014 [b]	0.332±0.032 [a]	0.273±0.024 [a]	0.295±0.027 [a]
NO_2-N (mg/l)	0.009±0.001 [c]	0.034±0.003 [a]	0.021±0.002 [b]	0.012±0.001 [c]
NO_3-N (mg/l)	0.164±0.014 [b]	0.412±0.045 [a]	0.343±0.032 [a]	0.19±0.016 [b]
Specific conductivity (mmhos/cm)	0.26±0.016 [c]	0.64±0.041 [a]	0.46±0.026 [b]	0.27±0.012 [c]

Different superscripts in a row indicate statistically significant differences (p<0.05).

Table 3. Growth (means±SE), rate of deformities, and survival in koi raised in different management regimes.

	Treatment			
Parameter	*Live food*	*Poultry manure*	*Cow dung*	*Control*
Harvest weight (g)	8.67±0.16 [a]	6.23 ± 0.18 [b]	4.37 ± 0.12 [c]	3.56 ± 0.11 [d]
Weight gain (g)	8.54±0.16 [a]	6.10±0.18 [b]	4.24±0.12 [c]	3.43±0.11 [d]
SGR (%/day)	5.45±0.14 [a]	5.03±0.10 [b]	4.56±0.07 [c]	4.30±0.07 [d]
Deformed individuals (%)	1.9 [d]	10.05 [b]	5.57 [c]	18.07 [a]
Survival rate (%)	96.16 [a]	90.5 [b]	81.86 [c]	70.60 [d]

Different superscripts in a row indicate statistically significant differences between means (p<0.05).

range to -0.01 to +0.01. According to this definition, food selectivity of koi larvae was clearly demonstrated in our results, with positive selection of cladocerans and negative selection of other groups.

Cladocerans were found in larger proportions in the diet than in the environment in all the treatments, implying that cladocerans constitute an important source of natural food for koi larvae in any culture system. The positive selection of cladocerans in all the treatments suggests that koi larvae prefer cladocerans despite the dominance of copepods in all but the live food treatment. This shows that koi larvae do not necessarily feed on the most abundant type of plankton. In the live food treatment, the cladoceran dominance resulted from the introduction of supplemental zooplankton cultured in plankton culture ponds with cladocerans as the major inoculum.

The feeding strategy of planktivores is based on the structure and functioning of their branchial feeding apparatus viz. gill rakers (Serajuddin, 2000). The presence of mucous helps to consolidate and transport food, possibly improving the retention efficiency of the filter. Characteristics such as the shape and size of the suspended particles and alteration capabilities of the mesh size of gill rakers also play important roles in food retention (Serajuddin, 2000). Food items may be rejected because they are larger than the mouth size of the fish.The koi larvae in our experiment were relatively young (0.13-8.67 g), and their mouth size may have prevented their consuming larger plankton. In nature, the small size of the carp fry mouth (Dabrowski and Bardega, 1984) acts as a constraint for optimal diet breadth during early stages (Werner, 1974).

The avoidance of food organisms may also be linked to taste, especially when fish probe the aggregation of food items and as demonstrated by the differential secretion of mucous by grass carp *(Ctenopharyngodon idella* Val.) in varied food conditions (Omarova and Lazareva, 1974). Negative selectivity in the manured and control treatments to outright rejection in the live food treatment of phytoplankton agrees with earlier experiments with other fish species including *Catla catla* Ham. (Jafri and Mustafa, 1975), brown trout, *Salmo trutta* L. (Fitzmaurice, 1979), and common carp, *Cyprinus carpio* L. (Chakrabarti and Jana, 1990).

The higher weight gain, SGR, and survival in the live food treatment could be attributed to the significantly higher abundance of cladocerans in that treatment. The highest concentration of zooplankton was in the live food treatment because of the regular addition of plankton to the ponds and as a result of the improved water quality (lower BOD, ammonium, and nitrite; higher DO and pH) that is conducive to reproduction of some of the zooplanktons that constitute the main food items for carp (Jana and Chakrabarti, 1993). The plankton intake of planktivorous fishes varies with feeding conditions. Jana and Chakrabarti (1990) reported that plankton intake of common carp, *Cyprinus carpio* L., in a live food system was higher than in a manured or control system.

The direct relationship between plankton intake and average body weight was demonstrated in carp by Chakrabarti and Jana (1991). The significantly lower weight gain, SGR, and survival rate in the control may have been due to an insufficient quantity of plankton in the system. From the experimental results, it seems that the larvae did not prefer the imported pelleted feed provided in this treatment, similar to results obtained in an earlier experiment (Jha et al., in press).

The observed deformities were mostly scoliosis and bent fins. Ornamental fish, unlike food fish, must be visually attractive to be marketable; deformed fish are aesthetically unattractive to potential customers. The percentage of deformed fish in the various treatments cannot be explained by the available data. The absence of any earlier report relating deformities in koi to husbandry management makes it difficult to draw conclusions. The deformities may have a genetic background since the experimental larvae were the offspring of a mixed commercial production of different koi types and randomly stocked in the ponds. They may also have been environmentally induced. The significantly higher percent of deformed fish in the control could be attributed to the lower abundance of plankton in the environment. A high incidence of deformities in fish fed commercial food was reported for crucian carp, *Carassius carassius* L. (Myszkowski et al., 2002).

From the findings of the present investigation, in which food selection of koi carp larvae reared under different management regimes in tropical ponds was reported for the first time, raising koi carp larvae in live food ponds with added plankton appears to be a better alternative than the conventional system of applying poultry manure or cow dung.

Acknowledgements

The authors are thankful to Mr. Kripan Sarkar of Rainbow Ornamental Fish Farm, Jalpaiguri, India, and his family for their cooperation during the field experiments. The authors also wish to express their gratitude to Dan Mires and an anonymous reviewer for their critical review and suggestions for upgrading the manuscript. The contributions of Dr. C.R. Nayak, Computer Center, and Miss Sushruta Jha, student in the Zoology Department, University of North Bengal, India, in the statistical analysis are gratefully acknowledged.

References

Adeyemo A.A., Oladosu G.A. and A.O. Ayinla, 1994. Growth and survival of fry of African catfish species, *Clarias gariepinus* Burchlet, *Heterobranchhus bidorsalis* Geoffery and *Heteroclarias* reared on *Moina dubia* in comparison with other first feed sources. *Aquaculture*, 119:41-45.

Akpan E.R. and N. Okafor, 1997. On organic fertilization and plankton development in two experimental freshwater ponds of Nigeria. *J. Aqua. Trop*., 12:147-154.

Al-Harbi A.H. and A.Q. Siddiqui, 2001. Rearing of common carp (*Cyprinus carpio* L.) larvae on dry and live food. *J. Aqua. Trop*., 16:231-239.

APHA, 1998. *Standard Methods for the Examination of Water and Wastewater,* 20th ed. American Public Health Association, Washington D.C. 1040 pp.

Asano L., Ako H., Shimizu E. and C.S. Tamaru, 2003. Limited water exchange system for freshwater ornamental fish. *Aquacult. Res*., 34:937- 941.

Beamish F.W.H. and I.M. Dickie, 1967. Metabolism and biological production in fish. pp. 215-242. In: S.D.Gerking (ed.). *The Biological Basis of Freshwater Fish Production.* Blackwell Scientific Publ., Oxford.

Bunnell D.B., Gonzalez M.J. and R.A. Stein, 2003. Zooplankton biomass enhances growth, but not survival, of first feeding *Pomoxis* spp. larvae. *Can. J. Fish. Aquat. Sci*., 60:1314-1323.

Chakrabarti R. and B.B. Jana, 1990. Food preferences and selection by common carp (*Cyprinus carpio*) fry under different feeding regimes. *J. Appl. Ichthyol*., 6:223-230.

Chakrabarti R. and B.B. Jana, 1991. Plankton intake as a function of body weight by common carp fry in different feeding conditions. *Aquaculture*, 93:21-34.

Crowder L.B., Mc Donald M.E. and J.A. Rice, 1987. Understanding recruitment of Lake Michigan fishes: the importance of size based interactions between fish and zooplankton. *Can. J. Fish. Aquat. Sci*., 44(Suppl. 2):141-147.

Dabrowski K. and R. Bardega, 1984. Mouth size and predicted food size preferences of larvae of three cyprinid fish species. *Aquaculture*, 40:42-46.

Dewan D., Wahab M.A., Beveridge M.C.M., Rahman M.H. and B.K.Sarkar, 1991. Food selection, electivity and dietary overlap among planktivorous Chinese and Indian major carp fry and fingerlings grown in extensively managed, rainfed ponds in Bangladesh. *Aquacult. Fish. Management*, 22:277-294.

Diana J. S., Lin C.K. and P.J. Schneeberger, 1991. Relationships among nutrient inputs, water nutrient concentrations, primary production, and yield of *Oreochromis niloticus* in ponds. *Aquaculture*, 92:323-341.

Feldlite M. and A. Milstein, 1999. Effect of density on survival and growth of cyprinid fish fry. *Aquacult. Int*., 7:399-411.

Fitzmaurice P., 1979. Selective predation of cladocera by brown trout *Salmo trutta* L. *J. Fish. Biol*., 15:521-525.

Garg S.K. and A. Bhatnagar, 1996. Effect of varying doses of organic and inorganic fertilizers on plankton production and fish biomass in brackish water fish ponds. *Aquacult. Res*., 27:157-166.

Hart T.F. and R.G. Werner, 1987. Effects of prey density on growth and survival of white sucker, *Catostomus commersoni*, and pumpkinseed, *Lepomis gibbosus* larvae. *Environ. Biol. Fishes*, 18:41-50.

Hjort J., 1914. Fluctuations in the great fisheries of northern Europe. *Rapp. P-V. Reun. Cons. Perm. Int. Explor. Mer.,* 20:1-228.

Ivlev V.S., 1961. *Experimental Ecology of the Feeding of Fishes.* Yale Univ. Press, New Haven. 302 pp.

Jafri A.K. and S. Mustafa, 1975. Food selection by young *Catla catla* (Hamilton–Buchanan) in a tropical fish pond. *J. Fish. Biol*., 10:437-440.

Jakubas M., 2002. Ecological aspects of pond fish culture intensification. 7. Zooplankton and benthos development in ponds of various intensification levels. *Arch. Pol. Fish*., 10(Suppl.3):87-102.

Jana B.B. and R. Chakrabarti, 1990. Comparison of plankton intake by Indian carp fingerlings under different feeding conditions. *J. Appl. Ichthyol*., 6:1-13.

Jana B.B. and R. Chakrabarti, 1993. Life table responses of zooplankton (*Moina micrura* Kurz and *Daphnia carinata* King) to manure application in a culture system. *Aquaculture*, 117:274-285.

Jha P. and S. Barat, in press. The effect of stocking density on growth, survival rate, and number of marketable fish produced of koi carps, *Cyprinus carpio* vr. *koi*, in concrete tanks. *J. Appl. Aquacult*.

Jha P., Sarkar K. and S. Barat, in press. Effect of different application rates of cowdung and poultry excreta on water quality and growth of ornamental carp, *Cyprinus carpio* vr. *koi*, in concrete tanks. *Turkish J. Fish. Aquat. Sci*.

Jhingran V.G., Natarajan A.V., Banerjea S.M. and A. David, 1988. Methodology on reservoir fisheries investigations in India. *Bull. Cent. Inland Capture Fish. Res. Inst*. (*Barrackpore*), 12:1-102.

Kinne O., 1962. Irreversible nongenetic adaptations. *Comp. Biochem. Physiol*., 5:265-282.

Lazzaro X., 1987. A review of planktivorous fishes: Their evolution, feeding behaviours, selectivities, and impacts. *Hydrobiologia*, 146: 97-167.

Miller T.J., Crowder L.B., Rice J.A. and E.A. Marschall, 1988. Larval size and recruitment mechanisms in fishes: towards a conceptual framework. *Can. J. Fish. Aquat. Sci*., 45:1657-1670.

Milstein A., Alkon A., Karplus I., Kochba M. and Y. Avnimelech, 1995. Combined effects of fertilization rate, manuring and feed pellet application on fish performance and water quality in polyculture ponds. *Aquacult. Res*., 26:55-65.

Mischke C.C. and P.V. Zimba, 2004. Plankton community responses in earthen channel catfish nursery ponds under various fertilization regimes. *Aquaculture*, 233:219-235.

Myszkowski L., Kaminski R., Quiros M., Stanny L.A. and J. Wolnicki, 2002. Dry diet influenced growth, size variability, condition and body deformities in juvenile crucian carp, *Carassius carassius* L., reared under controlled conditions. *Arch. Pol. Fish*., 10:51-61.

Omarova M.O. and L.P. Lazareva, 1974. Nutrition of *Hypophthalmichthys molitrix* (Val.) in water bodies of Daghistan. *Gidrobiol Zh*., 10:103-110.

Ricker W.E., 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada*, 191:1-382.

Rottmann R.W., Shireman J.V. and E.P. Lincoln, 1991. Comparison of three live foods and two dry diets for intensive culture of grass carp and bighead carp larvae. *Aquaculture*, 96:269-280.

Serajuddin M., 2000. Food selection by young *Catla catla* (Hamilton) and *Hypophthalmichthys molitrix* (Valenciennes) in a tropical fish pond. *J. Aqua. Trop*., 15:313-321.

Sokal R.R. and J.R. Rohlf, 1969. *Biometry - The Principles and Practice of Statistics in Biological Research*. H.F. Freeman and Co., San Francisco. 232 pp.

Ushakumari V.S. and C.M. Aravindan, 1992. Food selection and feeding habits of the Asian cichlid, *Etroplus suratensis* (Bloch), in a tropical lake. *J. Aqua. Trop*., 7:15-20.

Vinyard G.L., 1979. An ostracod (*Cypriodopis vidua*) can reduce predation from fish by resisting digestion. *Am. Midland Naturalist*, 102:188-190.

Welker M.T., Pierce C.I. and D.H. Wahl, 1994. Growth and survival of larval fishes: role of competition and zooplankton abundance. *Trans. Am. Fish. Soc*., 123:703-717.

Werner E.E., 1974. The fish size, prey size, handling time relation in several sunfishes and some implications. *J. Fish. Res. Bd. Canada*, 31:1531-1536.

Xie P., 1999. Gut contents of silver carp, *Hypophthalmichthys molitrix*, and the disruption of the centric diatom, *Cyclotella*, on passage through the oesophagus and intestine. *Aquaculture*, 180:295-305.

Xie P. and N. Takamura, 1996. Impact to filter feeding silver and bighead carp on the long term changes in the community structure of cladocera in Lake Donghu. *Acta Hydrobiol. Sin*., 20:47-59.