Tropical Agricultural Research Vol. 14: 60-71 (2002)

60

Determination of Compensatory Growth in Goldfish (*Carassius auratus*) Fry

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ABSTRACT. *Compensatory growth of fish is not only of theoretical interest, but has direct applications in aquaculture such as in achieving faster growth at a lower cost. This experiment was carried out to determine whether the stunted growth of goldfish during the post-larvae period (up to day 20) would be compensated by higher growth during the fry stage (from day 20-70) under different feeding regimes. Post-larvae raised in glass aquaria (0.06 m^2) in an indoor system at a stocking density of 500 fish/m^2 for stunted growth, were transferred on day 20 to cement tanks (1 m^2) in an outdoor system. Treatments (feeding regimes) used, with three replicates (tanks) each, were: (1) Artemia supplied throughout the experiment (Control); (2) first 20 days with microworm and subsequently with chicken manure (WM); (3) first 20 days with enriched microworm and subsequently with chicken manure (EWM); and (4) first 20 days with Artemia and subsequently with chicken manure (AM). On day 20, 30, 40, 50, and 60, live weight and total length of the fry randomly sampled from each replicate and percentage survival were measured. On day 70, all survivors were used for growth measurements. On day 20, WM and EWM recorded a significantly stunted growth ($P<0.05$) compared to Artemia feeds (Control and AM). However, at the end of the experiment, mean live weight, mean total length, mean specific growth rate and mean percentage survival did not show any significant difference ($p>0.05$) between MW, EWM, or AM versus the control. In addition, the final percentage survival was over 79% in all the treatments. This suggested that goldfish post-larvae, which have stunted growth up to day 20, could be able to catch up growth during their fry stage. The cost-benefit analysis of feeding regimes showed that this methodology can be used to minimize the production cost in goldfish farming systems, because Artemia is an expensive feed.*

INTRODUCTION

The international demand for fresh water fish has shown an increase in the past few years (Hettiarachchi and Cheong, 1994), and the ornamental fish trade has become an important source of foreign exchange for Sri Lanka (De Silva, 1985). In addition, it is becoming an income generating sector and provide job opportunities for people and the value of total exports of ornamental fish from Sri Lanka, which was 93 million rupees in 1991 increased up to 530.7 million rupees in 1998 (Anon, 1999). Sri Lanka has both necessary climate and water resources required for successful production of many species of fresh water ornamental fish and plants.

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Goldfish (*Carassius auratus*) is one of the most popular fresh water ornamental fish in the world as well as in Sri Lanka. It is an omnivorous fish, which eats all invertebrates and zooplankton that are found in natural waters. In artificial environments, feeds used for goldfish post-larvae rearing are *Artemia*, tubifex, mosquito larvae, daphnia and high quality granulated or pelleted feeds (Harvath and Seagrave, 1992).

Compensatory growth is defined as a phase of unusually rapid growth, following a period of under nutrition (Dobson and Holmes, 1984; Hayward *et al.*, 1997). Through this growth spurt, animals subjected to previous nutritional restriction may partially or completely catch up in body size with those that have not undergone food restriction (Dobson and Holmes, 1984; Russell and Wootton, 1992; Kim and Lovell, 1995). Compensatory growth in fish is not only of theoretical interest, but may also have applications in aquaculture (Quinton and Blake, 1990; Jobling *et al.*, 1994; Hayward *et al.*, 1997), as appropriate exploitation of this phenomenon may result in increased growth rate of fish larvae. Most studies of compensatory growth in fish larvae have been carried out on coldwater species (Schwarz *et al.*, 1985; Kim and Lovell, 1995; Hayward *et al.*, 1997) and reports on warm water species are scarce. Although goldfish is a valuable warm water ornamental fish species, compensatory growth does not seem to have been examined.

Feeding of fish has become one of the critical management practices of today, as it seems to be having a great impact on the growth rate and the survival rate of fish. *Artemia* have been adopted for larval culture of many species but such feeds are costly. Feed cost is the largest single operating expenditure in aquaculture, often representing over half of the total operating expense of a fish farm (Gerald and Scroeder, 1978). Therefore, it is important to find low cost culturing methods for those farmers to reduce farm operation cost. Treating outdoor ponds with chicken manure seems to be an inexpensive alternative to *Artemia* feeding. According to Boyd (1982) fertilized ponds continuously have more than 10×10^7 phytoplankton per liter and gross phytoplankton productivity is greater in fertilized ponds than in unfertilized ponds. Nutritional value of these natural food organisms in tanks is sufficient to support for excellent fish growth. They are a rich source of protein and often contain 40-50% crude protein on dry matter basis (De Silva and Anderson, 1995).

Therefore, the objectives of this study were: 1) to identify whether compensatory growth occurs; 2) to find out whether application of chicken manure could produce the required compensatory growth; and 3) to compare the financial profitability of different feeding regimes of goldfish larvae.

MATERIALS AND METHODS

Larvae sources

Day-old post-larvae used for the experiment were produced from the goldfish (Calico) broodstock maintained at the Department of Animal Science, University of Peradeniya. Prior to mating within the broodstock, males and females were raised in separate tanks for a period of two weeks with a special diet given three times per day to induce breeding. After two weeks, male and female parents were introduced to the breeding tank. Parents were separated after laying eggs to prevent feeding on eggs. Hatching occurred within 48 h after fertilization. One day after hatching, the post-larvae were removed and randomly allocated to the experimental units (0.06 m^2 glass aquaria).

Feed sources

Artemia (Great salt lakes) were hatched following the method described by Bengston *et al.* (1991). Microworms (*Anguillula silusae*) were cultured and separated using the method described by Parameshwaran (2001). Enrichment of microworm was done by adding coconut oil to the culture medium.

Experimental set-up

The day-old goldfish post-larvae were raised up to the end of post-larval period (20 days) in the glass aquaria in an indoor system at a high stocking density (500 fish/m^2). Such high density would create a stunting effect on growth of the post-larvae in the absence of a highly nutritious feed such as *Artemia*. On 20th day, the fish were introduced to outdoor cement tanks (1 m^2), in which they were raised at a density of 30 fish/m^2 up to the end of fry stage. The fry stage was defined as the period between 20th and 70th day of age. Four feeding regimes (treatments) were used for the experiment as shown in Table 1, each with three replicates.

Table 1. Description of the feeding regimes used in the experiment.

Treatment	Up to 20 days	20 days
1. Control	*Artemia*	*Artemia*
2. WM	Microworm	Chicken manure
3. EWM	Enriched microworm	Chicken manure
4. AM	*Artemia*	Chicken manure

For the WM, EWM and AM treatments, the selected outdoor cement tanks were fertilized with chicken manure. Initially, chicken manure mixed with dolomite at a ratio of 19:1 was applied as the basal fertilizer at the rate of 1000 kg/ha (dry weight basis). Thereafter, supplementary applications were made weekly at the rate of 100 kg/ha/week. After manuring, ponds were kept for a two-week period without any disturbance. Aeration was supplied to each tank. All the cement tanks were treated with kerosene at the rate of 2 ml/m^2 a day before the introduction of fish as a precautionary measure against predatory air breathing insects and repeated it every two weeks.

For growth measurements, fry were randomly sampled from each replicate at the age of 20, 30, 40, 50 and 60 days. Live weight (g) and total length (cm) of individual fish were measured. Number of dead fish was counted daily. At the end of fry stage (70 days of age), all the survived fish were counted and individual live weight and total length were determined. Percentage survival was estimated using the following formula:

$$\text{Survival (\%)} = \frac{\text{Number of fish survived during the culture period}}{\text{Number of fish introduced}} \times 100$$

Specific growth rate (SGR) at each growth stage of fry was determined by:

$$\text{SGR} = \left\{\frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Time (day)}}\right\} \times 100$$

Water quality measurements

Changes in physico chemical parameters of water in outdoor tanks treated with *Artemia* or chicken manure were monitored regularly. Temperature and pH of each tank were measured at weekly intervals in the early morning (0600 h) using an electronic instrument at a depth of 30 cm. Ammonia content was measured by the spectrophotometric method. In addition, weekly plankton counts were taken using a Sedwick-Rafter cell to identify differences in plankton growth between tanks treated with chicken manure and those with *Artemia*.

Proximate analysis

Chicken manure and live feeds (microworm and *Artemia*) were analyzed for proximate composition by standard techniques (AOAC, 1980). Crude protein content was determined by micro-kjeldhal method and fat by soxlet extraction. Crude fibre content was estimated by the fibre extraction apparatus.

Statistical analysis

Analysis of variance procedure was carried out for different growth stages of the fry separately to determine the differences among the four feeding regimes with respect to live weight, total length, SGR and percentage survival. Duncan's New Multiple Range Test was used to compare differences among the means.

The differences in physico chemical parameters (temperature, pH value and ammonia content) between the *Artemia* treated and chicken manure treated tanks were determined using Student's *t*-test. For this comparison, data from WM, EWM and AM were pooled to obtain the estimate for chicken manure group.

Economic analysis

Partial budget analysis was performed on the results to evaluate the profitability of the four feeding regimes considered. The expenses considered were the cost for feed and labour incurred during the period of growth (from hatching to 70 days of age) and the income was expected to be realized by selling the fish in the end. Input and output prices were based on current market prices.

RESULTS AND DISCUSSION

Water quality

Water temperature in the chicken manure treated tanks ranged from 24–26°C and in the control tanks ranged from 22-26°C (Table 2). Less temperature fluctuation observed in the manure treated tanks may be due to higher microbial activities with eutrification of manure. However, temperature in all the treatments were within the acceptable range of 20–28°C as identified by Albaster and Lloyd (1984).

Manure treated tanks showed lower pH values (7.5-7.9) than the control (8.0-8.5). However, pH value in all the treatment tanks were within the acceptable range of 6.5 and 9.0 (Boyd, 1982).

Table 2. Differences (Mean ± S.E.M.) in physico chemical parameters of water in *Artemia* treated tanks (Control) and the other (chicken manure treated) tanks combined.

Parameter	Treatment	
	Control	Chicken manure
Temperature (°C)	25 ± 0.37	23.5 ± 0.62
pH values	8.1 ± 0.07	7:7 ± 0.06
Ammonia (mg/l)	0.097 ± 0.003	0.085 ± 0.003

According to Boyd (1982), ammonia levels between 0.2 and 0.6 mg/l are toxic to many fish species. However, ammonia levels in all treatment tanks were between 0.095-0.106 mg/l throughout the experiment. The differences in the above physico-chemical parameters between chicken manure and control were not significant (P>0.05) which indicates that the dosage of chicken manure used would not have a negative effect on water quality.

Survival at the fry stage

Mean survival of all treatment tanks at the beginning of fry stage (20 days of age) was 91%. Survival of fish during the fry stage did not show a significant difference ($p>0.05$) among the four treatments (Fig. 1). However, mean percentage survival for all treatments at the end of fry stage was above 78%. Mortality occurred was mainly due to predator attacks in outdoor tanks. Main predators were backswimmer (*Anisops* spp.) and dragonfly larvae (*Pantala* spp.). Predator numbers were observed to be higher in manure treated tanks than in the control tanks. Though kerosene treatment reduced the predators, it did not completely eradicate them.

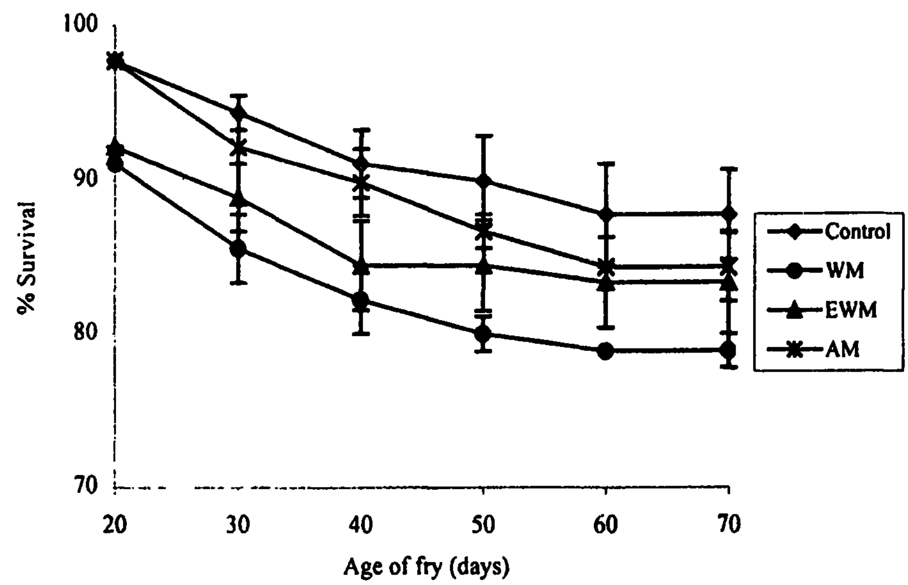

Fig. 1. Survival percentage (Mean ± S.E.M) of goldfish fry during experimental period.

Compensatory growth

At the beginning of fry stage, mean live weights (Fig. 2) and mean total lengths (Fig. 3) of treatments with microworms (WM and EWM) were significantly lower ($P<0.05$) than those with *Artemia* (Control and AM). Thus, the occurrence of stunted growth during post-larval period under WM and EWM was confirmed. It is clear from the results of proximate composition analysis of feeding material (Table 3) that *Artemia* feed which is used conventionally for post-larvae is a rich source of protein compared to microworms and chicken manure. Low protein availability in microworm feed compared to *Artemia* had been the critical factor causing growth retardation in post-larvae, particularly at the high stocking densities maintained. However, on the Day 70, there were no significant differences ($p>0.05$) among mean live weights (Fig. 2) or means of total length (Fig. 3) among the four treatments ($P>0.05$). These results indicate that the fry in WM and EWM treatments, which had low growth at the beginning due to under nutrition, had recovered completely by the end of the fry stage with the change in nutritional standards.

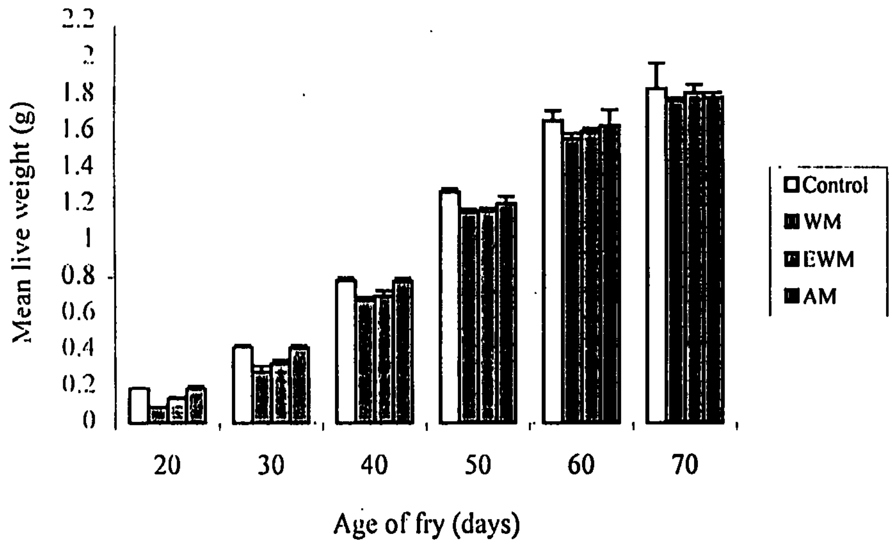

Fig. 2. **Mean live weight (Mean ± S.E.M) of goldfish fry during the experimental period.**

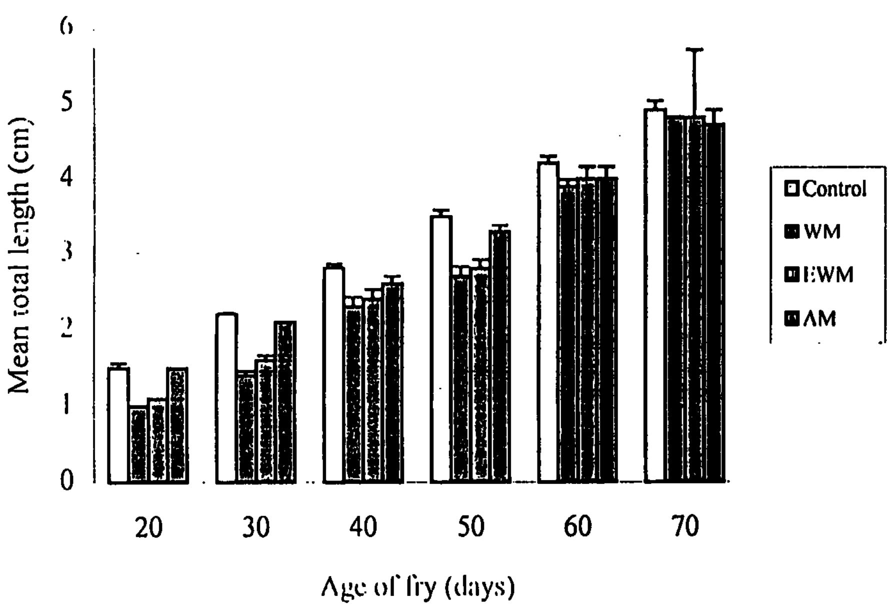

Fig. 3. **Mean total length (Mean ± S.E.M) of goldfish fry during the experimental period.**

Table 3. Proximate composition (% dry matter basis) of feeding materials.

	Artemia	Microworm	Chicken manure
Crude protein	51.0	39.7	22.0
Crude fat	18.9	19.8	1.8
Crude fibre	-	-	17.5
Ash	12.5	7.5	25.1
Moisture	4.0	31.8	19.7

Occurrence of compensatory growth (unusually rapid growth following a period of poor nutrition) can be clearly seen in specific growth rate patterns (Fig. 4). WM and EWM treatments continued to show significantly poorer growth (SGR) than the others ($P<0.05$) up to 30th day possibly due to the carry-over effect of poor nutrition during post-larval period. However, between 30th and 50th days, SGR of WM and EWM increased to the level that there was no significant difference among the four treatments ($P>0.05$). During the last stage of the fry (50-70 days), SGR of WM and EWM were significantly higher ($P<0.05$) than Control resulting in similar final live weights in all four treatments. Thus, overall SGR from Day 1 to Day 70 of the four treatments were not significantly different from one another ($P>0.05$).

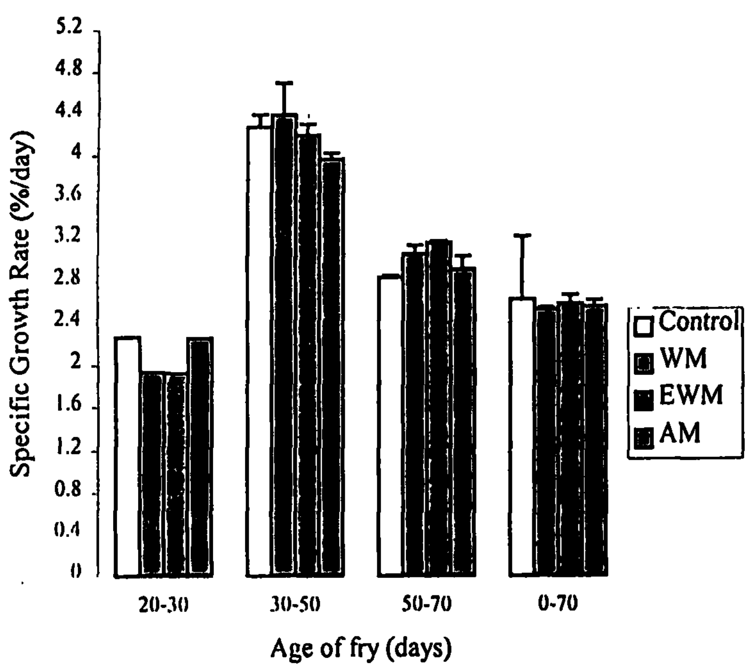

Fig. 4. Specific growth rate (Mean ± S.E.M) of goldfish fry during the experimental period.

Table 3 indicated that chicken manure has relatively low protein content. However, Sedwick-Rafter cell count showed that chicken manure treated tanks (WM, EWM and EM) had higher phytoplankton and zooplankton density than the control. Hence, natural food availability throughout the fry stage was higher in chicken manure treated tanks. The increase in feed consumption due to the abundance of natural feeds (phytoplankton and zooplankton) in chicken manure treated tanks seems to be the reason for compensatory growth. Similar incidences have been previously observed in warm-blooded animals (Mersmann *et al.*, 1987) and fish (Miglavs and Jobling, 1989). These results suggest that goldfish, as in warm-blooded animals (Szepesi and Epstein, 1977), will display accelerated growth for a period when allowed to feed to satiation following under nutrition. Hyperphagia may be the major contributor to the high growth rates during compensatory growth (Miglavs and Jobling, 1989; Russell and Wootton, 1992; Jobling and Koskela, 1996), and improved feed efficiency has been reported for some fishes showing compensatory growth (Jobling *et al.*, 1994; Qian *et al.*, 2000).

Whether the fish, which had stunted growth, can catch up body size to the level of the control depends on the duration of compensatory growth response. Data on the duration of compensatory growth in fish is limited. It was less than 20 days in minnow (Russell and Wootton, 1992), but was at least 50 days in juvenile Arctic charr (Miglavs and Jobling, 1989). The present study shows that goldfish larvae are capable of catching up body weight within 50 days under better nutritional environment.

Economics of feed

Results of the partial budget analysis on the four treatments are given in Table 4. Microworm seems to be the cheapest among all the feeds up to 20 days. Although microworm production is cheaper, large scale production of microworm may be a laborious process. However, small scale farmers can use microworms successfully. On the other hand, chicken manure also seems to be a cheaper by product and it is freely available. Problems are in the transport which requires higher labour for manuaring the tanks and the difficulty to use in indoor tanks. It was clear from Table 4 that Control showed a higher income than the other treatments due to slightly high (non significant) percentage survival. However, it gave the lowest profitability due to higher total production cost while WM showed the highest profitability. High profitability in WM was due to the ability of goldfish to show compensatory growth during the fry stage, under inexpensive chicken manure, which permits the use of inexpensive microworm feed during their post-larval period. Therefore, compensatory growth of goldfish can be used to minimize the cost of production and increase profitability of goldfish farming.

Table 4. Partial budget for different treatments.

	Control	WM	EWM	AM
a) Expenditure				
1) Feed cost (0-20 days)				
Average weight of feed (g/30 fish)				
Artemia	25 g	-	-	25 g
Microworm	-	1000 g	1000 g	-
Cost	25 g x Rs. 6.25 =Rs. 156.25	1 kg x Rs. 35.00 = Rs. 35.00	1 kg x Rs. 45.00 = Rs. 45.00	25 g x Rs. 6.25 = Rs. 156.25
2) Feed cost (20-70 days)				
-Average weight of feed and chicken manure (g/30 fish)				
Artemia	100 g	-	-	-
Chicken manure	-	1000g	1000 g	1000 g
Dolomite	-	50g	50 g	50 g
Cost	Rs. 625.00	Rs. 5.00	Rs. 5.00	Rs. 5.00
3) Labour cost	Rs. 3.00	Rs. 6.00	Rs. 6.00	Rs. 6.00
Total cost	Rs. 784.25	Rs. 46.00	Rs. 51.00	Rs. 167.25
c) Income (fish x price)	27 x Rs. 30.00 = Rs. 810.00	24 x Rs. 30.00 =Rs. 720.00	24 x Rs. 30.00 = Rs. 720.00	25 x Rs. 30.00 = Rs. 750.00
d) Profit	Rs. 25.75	Rs. 674.00	Rs. 669.00	Rs. 582.75

CONCLUSIONS

It is evident from this study that goldfish fry shows compensatory growth. This study also proves that, goldfish post-larvae stocked at 500/m^2 up to 20 days under microworm feed could produce stunted growth. However, they are capable of catching up the body weight completely during their fry stage with the provision of inexpensive chicken manure afterwards under outdoor conditions. Thus, the compensatory growth process of goldfish can be exploited by goldfish farmers to minimize production cost, as the conventional feeding method with *Artemia* is proven to be expensive.

ACKNOWLEDGEMENTS

Authors are thankful for CARP (Grant No. 12/391/289) for financial assistance.

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