Environment and Ecology 36 (2) : 508—513, April—June 2018
Website: environmentandecology.com ISSN 0970-0420

First Ever Weaning and Feeding Behavior of Hilsa Shad, *Tenualosa ilisha* (Hamilton,1822) Fry under Captive Culture in Freshwater Pond

D. N. Chattopadhyay, A. Chakraborty, P. K. Ray, R. N. Mandal, V. R. Suresh, S. K. Banik

Received 27 December 2017; Accepted 23 January 2018; Published on 12 February 2018

Abstract *Tenualosa ilisha,* a commercially important anadromous fish has declined drastically in nature. This study was aimed to culture the species and develop a weaning method for its domestication. The fry (29.5±0.26 mm/0.28 ± 0.01 g) were reared at 30000 nos. ha^{-1} in 0.1 ha freshwater pond where two feeding spots (S_1 and S_2) were selected at 3 m apart. Mixed zooplankton was supplied daily once at S_1 up to 36 days. The feed was applied daily at S_1 (8-10 days and 26-120 days) and S_2 (11-25 days). The fish voluntarily accepted plankton, but did not accept feed till 28 days. Initially they showed avoidance reaction towards feed though the quantity of plankton supply was reduced to 60% during 14-16 days. Further gradual reduction of plankton supply to 40%, 20% and 10% during 17-25 days, fish started moving to S_2 from small numbers to the entire population, indicating their habituation and social learning behavior towards feed. The continuation of 10% plankton supply resulted in involuntary ingestion of suspended feed during 29-35 days. The fish ingested feed voluntarily from 36th day and continued till 120 days. The present information on the feeding behavior and weaning may be useful for its domestication.

Keywords Weaning, Feeding behavior, Hilsa, *Tenualosa ilisha.*

D. N. Chattopadhyay*, A. Chakraborty, P. K. Ray
Regional Research Center, ICAR-Central Institute of Freshwater Aquaculture, Field Station of RRC, CIFA, Rahara, A-5 (Phase-III), Santalpara, Kalyani 741235, West Bengal, India

R. N. Mandal
RRC, ICAR-CIFA, Rahara, Kolkata 700118, Dist 24 Parganas (N), West Bengal, India

V. R. Suresh, S. K. Banik
ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata 700120, West Bengal, India
e-mail: deb.cifa@yahoo.com
*Correspondence

Introduction

Hilsa shad, *Tenualosa ilisha* is one of the most important anadromous euryhaline tropical fish that contribute to the commercial fishery in several countries including India, Bangladesh, Pakistan, Indonesia, Sumatra, Myanmar, Malaysia, Kuwait, Qatar, Oman, Thailand, Saudi Arabia, United Arab Emirates, Iraq, Iran, Sri Lanka and Vietnam [1]. The natural stock of hilsa has been drastically declining over the years. Hence there is an urgent need for development of its culture technologies in confined water.

Earlier attempts to culture hilsa in freshwater ponds were not successful as the fish did not survive beyond 120 days [2, 3]. Availability of preferable food and suitability of the environment are the essential

prerequisites for survival and growth of fish. In natural habitat, hilsa feeds on diatoms, green algae, copepods and cladocerans [4]. In pond culture, weaning the fish with nutritionally enriched artificial feed is essentially required for better survival and growth. Weaning is also generally accepted as an essential step for domestication of fish. The acceptance of artificial feed by hilsa fry through weaning has not been reported so far.

Considering the importance of weaning for pond culture of hilsa, an experiment was conducted to develop weaning protocol and feed training techniques for hilsa fry in freshwater pond through altered feeding strategies and methodologies according to the observed behavioral changes. The objectives of the study were to know (i) the behavioral changes of hilsa fry during feeding, (ii) whether plankton is preferred than artificial feed, (iii) whether fish can accept the artificial feed and (iv) whether fish can be fully weaned to artificial feed.

(The authors wish to express their gratitude to the Director, ICAR-CIFA, Bhubaneswar for providing the necessary facilities. Financial supports received from the National Agricultural Science Fund, ICAR, New Delhi under the project "Stock characterization, captive breeding, seed production and culture of hilsa (*Tenualosa ilisha*)'',project No. NFBSFARA/WQ-3021is duly acknowledged).

Materials and Methods

Hilsa fry (29.5 ± 0.26 mm/0.28 ± 0.01 g) of 50-d old were stocked in freshwater pond (0.1 ha water area and 1.5 m depth) at 30000 nos ha^{-1} stocking density and reared upto 120 days at Kalyani Field Station of RRC, CIFA, Rahara, West Bengal, India (Lat 22^0 57´43´´ N and Long $88^0$26´37´´ E). The fry were produced in fiberglass reinforced plastic (FRP) tanks after 46 days rearing of 4-d old larvae, which were obtained through artificial fecundation, hatching and larval incubation.

Thirty days before stocking, the pond was prepared by the application of mahua oil cake at 2500 kg ha^{-1} for removing unwanted fish followed by liming at 200 kg ha^{-1}. The fry were acclimatized in the pond for 7 days and then they were tested for acceptance of a

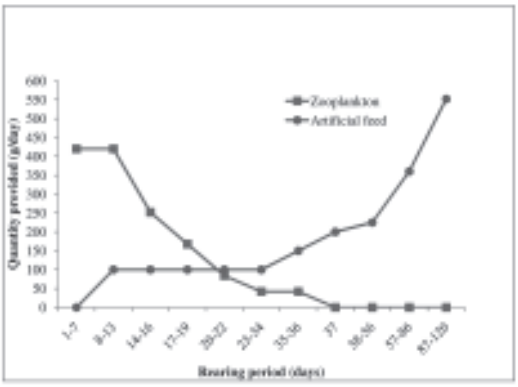

Fig. 1. Quantity of exogenous supply of mixed zooplankton (wet weight) and artificial feed (dry weight) to *Tenualosa ilisha* in freshwater pond during 120 days of rearing period.

commercial artificial feed (36% crude protein, 5% crude fat, 2% crude fiber, 11% moisture, 0.02-0.05 mm particle size and 0.01-0.02 m sec^{-1} sinking rate). At a distance of 1 m from the pond embankment two feeding spots designated as spot 1 (S_1) and spot 2 (S_2) were selected at 3 m apart. Mixed zooplankton consisting of rotifers, copepods and cladocerans was supplied exogenously daily once at S_1 during 1-36 days. Supply of plankton was stopped from 37-d onwards. Artificial feed was applied for a long duration of 40-120 minutes daily at S_1 during 8-10 days and 26-120 days and at S_2 during 11-25 days. Hand feeding was followed by broadcasting little amount of feed (3-5 g) each time at an interval of 1-2 minutes to minimize wastage of feed. During feed training period, feed was thus continuously broadcasted regardless of the appearance of fish in the feeding spot and feed acceptance. Both plankton and artificial feed were supplied at 10:00 h.

Figure 1 presents the quantity of exogenous supply of plankton and artificial feed to *Tenualosa ilisha.* The period from the first day of feed supply to the day when all the fish started accepting the feed actively without exogenous supply of plankton was considered as the feed training period (8-37 days) for weaning. Initially the fish were supplied with a small fixed quantity (50% of body weight of total stocked

Table 1. Specific objectives and feeding schedule during weaning period of *T. ilisha.*

Sl. No.	Specific objectives	Days of rearing	Exogenous supply of plankton and feed: Plankton quantity	Feed supply spot
1.	To know whether hilsa fry are attracted towards plankton and accept at a particular site in pond	1-7	Total 420 g (wet weight)	No feed was applied
2.	To observe whether the fish voluntarily accept artificial feed or not in presence of sufficient plankton	8-10	Same as during 1-7 days	S_1 (where fish browsed plankton)
3.	To observe whether the fish are attracted towards feed in other spot where plankton is not supplied	11-13	Same as during 1-7 days	S_2 (when fish browsed plankton at S_1)
4.	To observe whether fish move to feed supply spot and voluntarily accept feed in absence of sufficient natural food at S_1	14-16	Reduced to 60%	S_2 (when fish browsed plankton at S_1)
		17-19	Reduced to 40%	S_2 (when fish browsed plankton at S_1)
		20-22	Reduced to 20%	S_2 (when fish browsed plankton at S_1)
		23-25	Reduced to 10%	S_2 (when fish browsed plankton at S_1)
5.	To habituate the fish with feed along with low quantity of plankton supply at the same spot as it is expected that fish may consume feed either possively (involuntary ingestion of feed along with plankton) or actively (voluntary ingestion of feed) when they are hungry	26-36	Same as during 23-25 days	S_1 (where fish browsed plankton)
6.	To observe whether fish reach at the feeding spot in absence of plankton and to train the fish to feed exclusively on artificial feed	37-120	Plankton supply stopped	S_1 and within 3 m radius

fish) of artificial feed. As they started consuming more, they were fed *ad libitum* up to their satiation; feed supply was stopped when the fish did not accept the feed or leave the place. In accordance with the behavioral changes, feeding schedule was altered with specific objectives to train the fish for accepting feed (Table 1). The period from the day after completion of the training period to the end of the experimental period was considered as a post training period.

Periodically, 5 fish were randomly caught after completion of feeding and dissected for confirmation of the presence of artificial feed in the stomach. During feeding, the behavioral changes were observed daily. Length and weight of fish were measured before stocking and at 30-day intervals from randomly collected 30 fish each. Water quality parameters were analyzed at 30-day intervals at 8:00 h following APHA [5] and by using instrument (PCSTEST35, Eutech Singapore-Oakton USA).

Results and Discussion

During first six days of acclimatization period, no fish appeared at S_1. Since the fish were stocked in the pond from ERP tanks in which they were habituated to detect plankton easily because of small confined areas of the tanks, the new larger pond environment was possibly difficult for them to identify the particular spot where sufficient plankton was provided. However, gradually the fish could identify the spot by 7th day of rearing and was attracted towards natural food. The fish appeared at S_1 as shoal and started browsing plankton voluntarily. Table 2 describes the changes in feeding behavior during feed training and post training period in different days of rearing period.

During the training period of weaning (8-37 day), fish did not accept feed up to 28 days. Involuntary feeding behavior (ingestion of feed particles along

Table 2. Behavioral changes during feed training and post training period of *T. ilisha.*

Days of rearing	Behavioral changes
8-10	Whenever feed was applied, fish reacted immediately and ran away from the place. However, they returned back after 3-4 minutes and started browsing plankton. Such occurrence was observed for 4-5 times and finally fishes disappeared from this place and did not return back.
11-13	Fish browsed plankton at S_1. They neither left the place, nor did they move to S_2. However, after completion of feeding plankton they left the spot.
14-16	Despite the 60% reduction of plankton supply, fish showed similar behavior as was in last 3 days.
17-22	When the plankton supply was further reduced to 40 and 20% each for consecutive 3 days, it was observed that after completion of feeding plankton some fish moved to S_2 however, still they did not accept the feed and left the spot.
23-25	Further reduction (10%) in supply of plankton resulted in movement of all fish to S_2 but still they did not accept feed and left the spot.
26-28	Whenever feed was applied, fish did not left the feeding spot and few fish break their speed near the feed particles but not yet accepted.
29-31	Some fish started feeding involuntarsily while others moved to surrounding areas of feeding spot horizontally.
32-35	Most of the fishes started ingesting the feed particles involuntarily by horizontal movement through the feeding area at the subsurface are where the feed was ahout to sink slowly from water surface.
36	Fish in shoat was found to feed actively and voraciously in circular motion around the feed at the subsurface area where the feed was about to sink slowly from water surface. They also moved to other surrounding areas where feed was broadcasted.
37	Similar active feeding behavior was also observed like previous day in absence of exogenous supply of plankton. They also moved to other surrounding areas where feed was broadcasted.
38-56	Fish fed actively on feed anywhere surrounding the S_1 and quickly moved from one place to another immediately after feed application.
57-86	Feeding behavior in circular motion was observed to continue as previous days. Normally they engulfed feed particles in sinking condition. It was observed that when there were no feed particles in subsurface layer, some fish moved vertically to the water surface and hit the floating feed mass by their snout. As a result the feed particles started sinking and they consumed from subsurface layer of water.
87-120	Fish shoal were found moving near the feeding spot before application of feed. When feed was supplied they started feeding actively like previous days.

with plankton) was observed during 29-35 days. Fish started feeding actively (voluntary ingestion) on 36th day along with plankton. When plankton supply was stopped from 37th day, fish continued feeding actively till the end of 120 days, Therefore, from the 37th day onwards fish are regarded as fully weaned.

During first 3 days of feed training (8-10 days), avoidance behavior towards feed was observed. The fish moved away when feed was supplied along with plankton. But possibly due to hunger and the availability of sufficient plankton they returned back to the same spot and started feeding plankton. Repetition of feed application on the same spot interrupted their normal feeding; hence they finally disappeared from the spot and did not come back.

The feeding behavior indicated that hilsa voluntarily accept plankton when offered exogenously and also the plankton is preferred food than artificial feed. The fish did not move to feed application spot (S_2) from the spot where plankton was sufficiently available as observed during 11-13 days. Even a 60% reduction of plankton supply could not change their

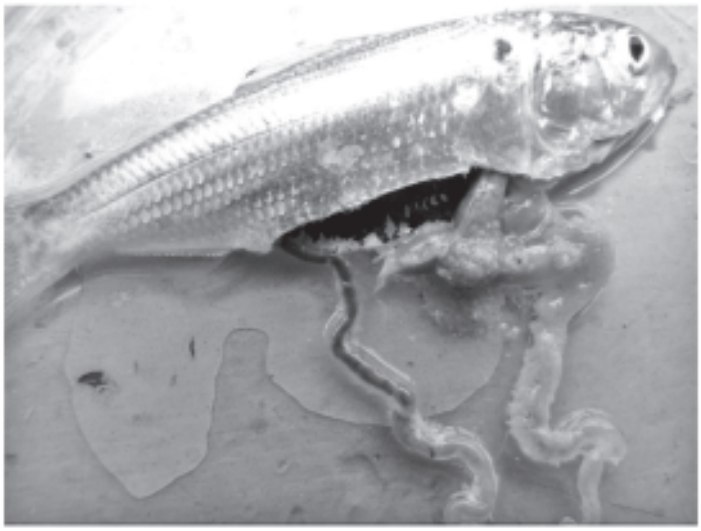

Fig. 2. Presence of artificial feed in gut of pond reared hilsa fry.

behavior in the next 3 days of training. Further reduction of plankton (40%, 20% and 10%) during 17-25 days of rearing, could make their behavioral change. Since, less quantity of supplied plankton was not sufficient to satiate them and possibly they assumed the small, slow sinking feed particles as plankton, the entire shoal of fish started moving gradually day by day to the feed application spot (S_2) in search of preferred food. But as the fish did not find plankton they left the spot without accepting the feed.

However, continuous application of feed along with quantity of plankton during 26-36 days, the entire fish population could be habituated to ingest feed starting from passive to active feeding phase when they could recognize the palatable nature of feed particles. Attraction towards feed and acceptance by the fish from small numbers to the entire population in the pond indicated their social learning behavior [6]. Initial passive feeding behavior, possibly triggered them to feed actively through recognition of feed palatability,texture, flavor and size. Habituation and associative learning behavior in fish as described by Tyus [6] was clearly found in hilsa.

During the phase of active feeding (36-120 days), fish feed by schooling together with vigorus movement and became so accustomed to feed that they did not leave the place while feeding, despite any external disturbances like gathering of people or making noise near the pond dyke.Fish became so habituated with feed during post training period (37-120 days) that without the application of plankton they appeared at the feeding spot in particular time when they were trained for feeding. Figure 2 shows the presence feed particles in the stomach of pond reared hilsa fry and confirms for the first time that hilsa fry accepted artificial feed under captive rearing in freshwater pond condition attempted so far.

It was observed that hilsa neither nibbled plankton and feed particles nor they remained stationary during feeding as normally found in carps. Rather, they swam very fast through the plankton and feed particles, keeping wide opening of their mouth and opercula so that food items along with water could easily enter through the mouth and subsequently got filtered by their gill rakers. Fish were never found to

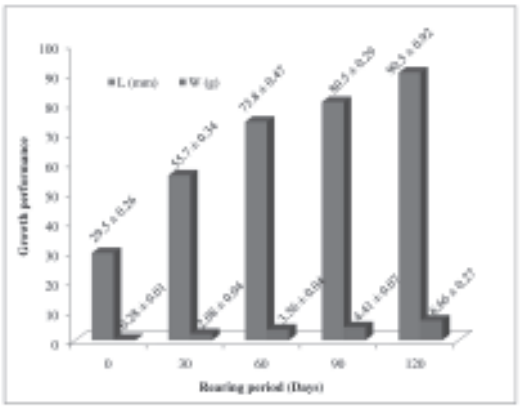

Fig. 3. Growth performance of *Tenualosa ilisha* fry during 120 days rearing in freshwater pond.

take the feed that were lying on the concrete wall of the dyke. However, they often consumed those feed particles which came up and were suspended by their tail movement. When there was no feed, they started moving along the pond side. Our results directly evidenced that hilsa is a visual feeder. De and Datta [7] also reported that hilsa searches food by sight. However, their interpretation was based on the indirect evidence as absence of taste buds in hilsa. Our results also indicated that in pond culture, hilsa consumed feed in suspended condition from the subsurface and column layer and not from the bottom, which is in contrast with the findings Shafi et al. [8] who reported that hilsa is a bottom feeder in natural waters.

Figure 3 presents the growth performance of hilsa during 120 days of experimental period in pond. The qualities of water during experimental period were 8.38 ± 0.03 ph, 8.4 ± 0.11 mg L^{-1} dissolved oxygen (DO), 0 mg L^{-1} free carbon di-oxide (CO_2), 154 ± 22.27 mg L^{-1} alkalinity, 319 ± 52.18 mg L^{-1} hardness, 380.2 ± 22.04 mg L^{-1} salinity, 741.8 ± 60.79 µS cm^{-1} conductivity and 539.4 ± 27.72 mg L^{-1} total dissolved solids (TDS). The water quality was within the range of aquaculture standards [9, 10].

Conclusion

Hilsa fry did not immediately accept artificial feed. However, they could be trained to accept feed through gradual reduction of exogenous supply of plankton with simultaneous increase in supply of artificial feed. The first ever information described in this study on the feeding behavior and method of training for successful weaning of hilsa fry under pond condition is a step closer to its domestication. This method may be useful for production of fingerling, which serves as the stocking material for further culture in grow out pond to produce table size fish. Besides, stocking of such fingerlings that have been already weaned have a greater advantage for grow out culture over the fingerlings of riverine collection.

References

1. Freyhof J (2014) *Tenualosa ilisha.* The IUCN Red List of Threatened Species : e.T166442A1132697.
2. Malhotra JC, Shah KL (1979) Hilsa-its breeding and possibilities of culture. Souvenir in commemoration of the ICAR Golden Jubilee Year, CIFRI. Barrackpore, Part II, pp 175—178.
3. Sen PR, De DK, Nath D (1990) Experiments on artificial propagation of Hilsa, *Tenualosa ilisha* (Ham.). Ind J Fish 37 : 159—162.
4. Hasan KMM, Ahmed ZF, Wahab MA, Mohammed EY (2016) Food and feeding ecology of hilsa *(Tenualosa ilisha)* in Bangladesh's Meghna River basin. IIED Working Paper, IIED, London, pp 20.
5. APHA (2012) Standard methods for the examination of water and wastewater (22nd edn.). Published by American Public Halth Association, American Water Works Association and Water Environment Federation, Washington, Dc, United Kingdom.
6. Tyus HM (2012) Ecology and conservation of fishes, CRC Press, Taylor & Francis group. Boca Raton, pp 515.
7. De DK, Datta NC (1990) Studies on certain aspects of the morpho-histology of Indian shad hilsa, *Tenualosa ilisha* (Hamilton) in relation to food and feeding habits. Ind J Fish 37 : 189—198.
8. Shafi M, Quddus MMA, Hossain H (1977) Observations on the food and feeding habits of young *Hilsa ilisha* (Hamilton-Buchanan) from the river Dhaleswari. In : Proc, 2nd Bangladesh Sc Conf, Dhaka, Bangladesh, A-40.
9. Alabaster JS, Lloyd R (1982) Water quality criteria for freshwater fish (2nd edn.). Butterworth, London.
10. Boyd CE, Tucker CS (1998) Water quality and pond soil analyses for aquaculture Alabama Agric Experim Station, Alabama.