The feeding habits and development of digestive system of *Labeo victorianus* Blgr (pisces: cyprinidae)

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Abstract

The goal of the current research effort is to revive through aquaculture, the population of *Labeo victorianus* ("Ningu"), a previously important commercial fish species of Lake Victoria but now threatened with extinction. The specific focus of the study was to obtain sufficient understanding of the feeding biology and adaptations of *L. victorianus* to changes in diet during growth to enable development of diets for commercial aquaculture production.

Specimens of "Ningu" were collected from the mouths of Rivers Kagera and Sio on monthly basis for an entire annual cycle. The composition of the gut contents were analysed to determine the feeding habits. The structure of the digestive system was studied to determine the adaptations of the system to its diet. Ripe broodstocks collected from the mouth of River Sio during peak spawning were successfully induced to spawn in station ponds at Kajjansi using a hormone and incubated in pond and tanks to hatch. The process of weaning from the yolk food reserve (endogenous feeding) to external (exogenous) feeding, the starter (weaning) diet and the development process of the digestive system were recorded.

Results so far show that the adult "Ningu" is an omnivore predominantly feeding on detritus material consisting mainly of plant material. The digestive system has no stomach and consists of an extremely elongated gut with intestinal length ranging from 7 to 11.8 times the body length. This is typical of predominantly herbivorous animals. Spawning of fish induced at 5.00 pm occurred overnight at temperatures of 19-20 ^{o}C. Hatching of eggs started after 10 hours and lasted up to 18 hours at the above temperatures. The yolk sac food reserve lasted from five to six days before the larvae were able to take in external food. The development of the digestive system, including the liver, pancreas and the secretary and absorptive epithelia, was sufficiently advanced by day four to enable the larvae to start external feeding. Weaning to exogenous (external) food source started on the fifth day after hatching. Zooplankton, especially rotifers, were found to be the most suitable starter diet and then the larvae gradually shifted from a predominantly animal diet towards a predominantly plant diet as it grew. The larvae of "Ningu" were unable to utilize plant diet until they were two weeks old. The larvae were able to take in and utilise dry diet from three weeks and a formulation of Maize bran (40%), "mukene" 33%), baby soya food (25%) and mineral premixes (2%) gave reasonable survival and growth.

The quick development of the swim bladder and the pectoral fin after one and two days, respectively, was found to be very important for survival of the larvae, facilitating escape from predators and searching for food.

Key words: Induced spawning, yolk sac, endogenous feeding, exogenous feeding, weaning

Introduction

Fish catches from the major lakes in the East African Region are on the decline and a number of indigenous fish species are threatened with extinction (Uganda Fisheries Department Annual reports, 1988; Ogutu-Ohwayo, 1990a, 1990b; Ogutu-Ohwayo and Okaronon, 1996). Among the previously most popular indigenous species of Lake Victoria that are now referred to as endangered (LVEMP, 1997) is *Labeo victorianus*, locally known as "Ningu" in East Africa. The "Ningu" had been described by Cadwalladr, (1965, 1969) as a commercially important migratory fish of Lake Victoria and also one of the most abundant fish landed. From the 1950's, however, the number of fish landed dropped significantly and by the mid 1960's *Labeo victorianus* had virtually disappeared in the catches as shown in Figure 1 (Cadwalladr, 1965, 1969). The 'Ningu" is exploited during rains when sexually mature fish collect at river mouths on their migration route to spawning grounds. Owing to the exploitation at this stage in its life history, there began a decline in 'Ningu" population, especially as the less efficient traditional methods of reed traps were replaced by the more efficient gill-net methods during the 1930's and 1940's (Cadwalladr, 1965).

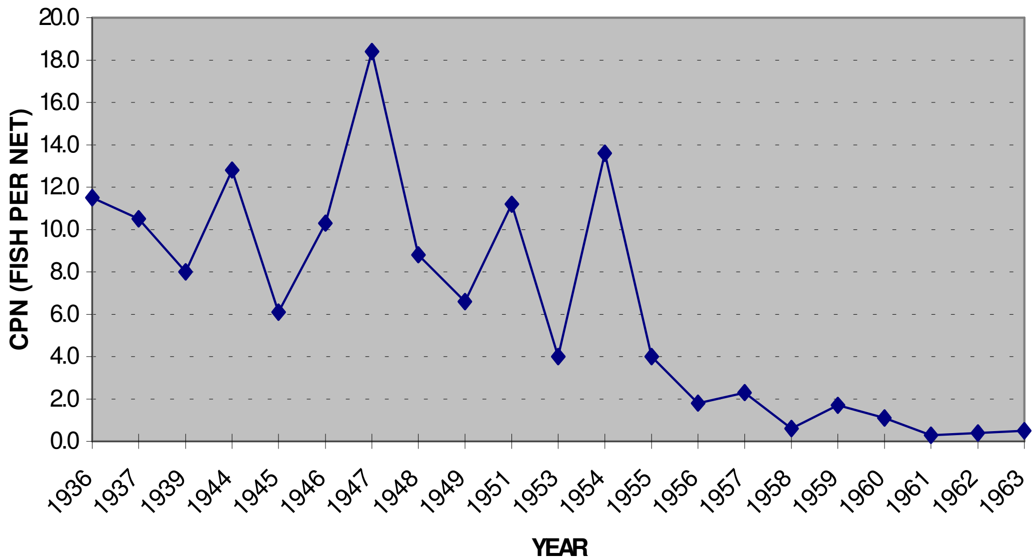

Figure 1. Annual catch records of *Labeo victorianus* for River Kagera. Source: Cadwalladr (1965)

In its effort to revive the populations of endangered fish species indigenous to Lake Victoria, the Lake Victoria Environmental Management Project (LVEMP) selected *Labeo victorianus* among the top priority species for revival (LVEMP, 1997).

The goal of the present research effort is to revive the population of 'Ningu" through commercial aquaculture production. The two most important pre-requisites for domesticating any animal are being able to **breed** and to **feed** the animal in captivity (De Saliva and Anderson, 1995). In turn, a full understanding of the feeding habits and the adaptations to these habits is crucial to development of quality feed for that animal (De Saliva and Anderson, 1995).

Objective

The objective of the study is to understand the feeding biology of 'Ningu" in order to be able to develop appropriate feeds for the different developmental stages of the fish. The specific objectives were:

i. To understand the digestive system of 'Ningu"
ii. To determine the feeding habit of 'Ningu",
iii. To determine the earliest time to start feeding, 'Ningu" larvae,
iv. To determine the most suitable starter diet that gives best growth and survival and the earliest time the 'Ningu" is able to utilise dry formulated feed.

v. To determine the development of the digestive systems and the adaptations of 'Ningu" to the feeds for the different developmental stages

Significance of the study

i) *Labeo victorianus* is a very popular fish that fetches high market price. Its commercial production in ponds will be a very profitable enterprise.
ii) The natural stocks of *Labeo victorianus* have been threatened. Commercial production of the fish in ponds could be a way of reviving the population and/or ease pressure on natural stocks.
iii) Details of the nutritional requirements for the different developmental stages of 'Ningu" and adaptations to different diets that would enable development of these diets are not known.
iv) There are many other Cyprinids similar to 'Ningu" with equally high aquaculture potential which could benefit from the knowledge acquired in the study of development of food for *Labeo victorianus.* This could give useful clues to development of other indigenous Cyprinids with potential for aquaculture, such as *Barbus* spp.

Materials and methods

Shallow (up to 20 m deep) inshore areas of Lake Victoria around the mouths of Rivers Sio and Kagera were randomly sampled and interviews with fishermen conducted to identify sampling areas. *Labeo victorianus* lives in the shallow inshore waters 0-20 m deep from where ripe adults migrate into rivers to spawn during rains (Greenwood, 1965; Cadwalladr, 1965, 1969; Kudhongania and Cordone, 1974).

Fish samples were collected every month for a complete annual cycle from the mouths and along Rivers Kagera and Sio. Fishing was done using gill nets of assorted mesh sizes of 1½", 2", 2 ½" and 3" mounted by the 50% and operated by drifting along the rivers. Other samples were also purchased from fishermen, when catches were very low. Each individual fish was weighed and measured then cut open to remove the viscera and other organs before weighing again. Parameters including sex, maturity stage, total weight, fork and standard lengths, weight of gut, weight of mesenteric fat, weight of gonad and the weight of the gutted fish were recorded. The entire gastro-intestinal tract (GIT) for each fish was preserved in Bouin's solution and secured in sample bottles for laboratory analysis.

Some fish not so badly hurt by the gear were transported in 500 litre water tanks under aeration and stocked in station ponds at Kajjansi for breeding trials. The lengths of straightened GIT were measured and the morphology and anatomy of the entire GIT from lip to the anal opening were studied after histological processing and staining using standard histological methods.

The contents were stripped onto a watch glass, blotted dry and weighed to the nearest 0.01g. The contents of the first part of the gut were emptied onto petri dishes, isolated into major food categories and quantified using the subjective technique modified from Pillay, (1952), which gives volumes occupied by each food category as percentage of total volume.

Three pairs of ripe broodstocks, collected from R. Sio at the peak of spawning season in April, 2001 and held in Kajjansi Station ponds for three days to acclimate, were induced to spawn at 5.00 pm on 18 April, 2001. Aquaspawn hormone was administered by intra-muscular injection around the mid dorsal region at a rate of 0.5 ml/kg of fish and the fish put in 1 x 2 x 0.5 m nylon 'happa" lined with curtain liner material with mesh sizes about 0.2 mm to hold the fry. Spawning occurred overnight. Some eggs were left in the 'happa" in the pond and others tra nsferred into fibre glass nursing tanks placed on the veranda. For both systems, water temperature, pH, ammonia and dissolved oxygen were recorded at six hourly intervals. Hatching started at around 11.00 am and lasted over 18 hours. The larvae were inspected under the microscope daily to determine when the yolk food reserve was exhausted and when external feeding could be started. The first larvae with food in the gut were seen on the fifth day after hatching. From that time the fry were fed on water of predominantly zooplankton culture.

Two weeks prior to inducing spawning two sets of culture systems for the live food for the expected fry were set up. One consisted of compost of rotting vegetation and dry chicken manure in 1,000-litre asbestos tanks and another one was in ponds enriched with soaked sunflower cake at 10 kg/100 m^3 of water. A plankton community rich in zooplankton (mainly rotifers) and some phytoplankton developed after two weeks. Water samples from these systems were collected and fed to the larvae in the various nursing systems. Samples of the larvae were collected on daily basis and fixed in Bouin's solution for study of development of the digestive system.

Weaning from endogenous feeding (on yolk reserve) to exogenous feeding started on the fifth day from hatching. Three sets of experiment were set up in triplicate in glass aquaria to determine whether phytoplankton or zooplankton or a combination of both as starter food gave the best growth and survival of the larvae of 'Ningu". One se t had zooplankton only, predominantly rotifers. The second set had phytoplankton only, algae of mixed species; and the third set contained mixtures of zooplankton and phytoplankton in about equal portions (about half the concentration as in set 1 and 2 above). Each of these 10-litre tanks were stocked with 40 fry of 'Ningu" with predetermined total lengths. The tanks were adequately aerated, stocks of the respective food items replenished every two days and water was replaced every two weeks. Initially the total lengths of individual fish were measured to the nearest mm, later individual weights of fish larvae were taken to nearest 0.001 g, and the number surviving was counted every month for three months.

Another set of experiments was run to determine at what size the fry of 'Ningu" started taking in dry formulated feed. Two different sizes; the 3 week old (7.2 mm) and the 5 week old (12.3 mm TL); juveniles were stocked at about 40 fish per 5 litre aquaria which was filled with fresh water from a spring well. A formulation of dry diet that had been commonly used at the Station to feed fish consisting of maize bran 43%, *Rastrineobola argentea* ("mukene") 30 %, Baby soya 25% and mineral/vitamin premix 2% was fed to the 'Ningu" fry at 10% body weight fed in mo rning and in the afternoon. The feed was ground fine and sieved through a 200 μm mesh to allow the fry with its small mouth take it. The water was adequately aerated and replaced once every week. The total length of the fish (initially) and its weight (later) were recorded individually and the number of the fish surviving was recorded each month for four months. Later on proximate analysis of the formulated diet was done to determine the amount of protein, lipid, energy and minerals it contained. Later fresh tissue of the juvenile fish was analysed to get the composition of protein, lipids, energy and mineral. This composition gives an approximation of the dietary requirements of the fish to which the formulated diet should be matched (De Saliva and Anderson, 1995).

In Asia one of the best growths of the Asian Cyprinids is obtained from ponds treated with vegetable oils (Gregory, pers. comm, 2001). A set of trials with a local vegetable oil was set up to try and maintain growth of 'Ningu" in ponds to allow further observations on the development of the digestive system. Two 100 m^2 ponds were drained to eliminate any other fish from the pond and necessary repairs made the pond. The ponds were limed with 25 kg of builder's white lime spread at the pond bottom to raise the pH. The ponds were then flooded with fresh water passed through fine screens to prevent entry of wild fish. Sunflower cake, (2 kg per 100 m^2 pond) was soaked overnight to form a slurry and sprinkled throughout the ponds. This treatment was repeated every week. Fish samples were removed every month for study of the development of the digestive system. Opportunity was also taken to monitor performance of 'Ningu" in sunflower cake -treated ponds by recording the weights and total lengths of individual fish in the samples each month.

Results

The mouth of 'Ningu" is ventrally positioned and has soft and retractable lips bearing soft teeth-like barbs with soft-toothed pads. There is no evidence of pharyngeal teeth in 'Ningu" but the buccal cavity h as a hard pad on the upper palate. The oesophagus is a short (1 cm) muscular tube whose epithelium contains goblet cells for mucous secretion to lubricate food during swallowing. There was no evidence of digestion in the oesophagus. 'Ningu" has no stomach. The oesophagus leads to a relatively large intestinal bulb about a quarter the length of the intestine, which then tapers to a relatively smaller intestinal tract, ending at the anal pore. The intestine of the adult 'Ningu" is extremely long, ranging from 7 to 11.8 times the fork length of the fish as shown in Table 1 and Figure 3. Over 90% of the intestinal length is coiled into several concentric circles to fit the belly of the fish.

The gut content of 'Ningu" was dominated by detritus (40%) consistin g mainly of plant parts followed by algae (30%). Insect and insect parts, zooplankton (mainly rotifers) and unidentifiable materials occurred in almost equal parts (10% each). The results are shown in Table 2 and Figure 2 below.

Table 1. The gut length of *Labeo victorianus* and other fish species in relation to feeding habit (extracted from De Saliva and Anderson, 1986)

Species	Feeding habit	RGL[NinguGreenwood] MIN	RGL MAX
Ptychocheilis oreganensis (Rich.)	Carnivorous	0.78	0.78
Chela hacaila (Ham.)	Carnivorous	0.88	0.88
Barilius moorei (Blgr.)	Carnivorous	0.65	0.8
Elopichthys bambusa (Rich.)	Carnivorous	0.63	0.63
Erythraculta erythropterus (Bas.)	Carnivorous, insects	0.77	1.5
Chelethiops elogatus (Blgr.)	Zooplankton	0.75	0.75
Engraulicypris minutus (Blgr.)	Zooplankton	0.7	0.7
Leptocypris modestus (Blgr.)	Invertebrates	0.8	1
Rostrogobio amurensis (Tar.)	Invertebrates	0.8	1.4
Barbus ticto (Gunth.)	Invertebrates, plants	1.58	1.58
B. tor (Ham.)	Invertebrates, plants	1.24	1.24
B. sharpeyi (Gunth.)	Plants	2.79	3.18
Amblypharyngodon mola (Ham.)	Plants	2.8	2.8
*Ctenopharyngodon idella** (Val.)	Plants	2.5	2.5
Ladislavia taczanowski (Dyb.)	Algae, invertebrates	2	2.5
Garra dembensis (Rupp.)	Algae, invertebrates	4.5	4.5
*Catla catla** (Ham.)	Periphyton, plants, insect larvae	4.68	4.68
Varicorhinus herratensis (Keys)	Algae, detritus	6	7.5
*Hypophthalmicthys molitrix** (Val.)	Phytoplankton	13	13
*Cirrhina mrigala** (Ham.)	Algae, detritus	8	8
Labeo calbasu (Ham.)	Plants, weeds, algae, diatoms	3.75	10.33
L. limeatus (Blagr.)	Algae, detritus	16.1	16.1
L. horie (Cuv.)	Algae, detritus	15.5	15.5
L. victorianus, adult		7	11.08
L. victorianus, juveniles		0.67	2.94

[1] RGL = Relative gut length (gut length divided by total length of the fish)

Table 2. The composition of the gut content of 'Ningu".

Food category	**Percentage**
Detrital materials	40%
Algae	30%
Insecta	10%
Rotifers	10%
Others (Unidentified)	10%
Total	**100%**

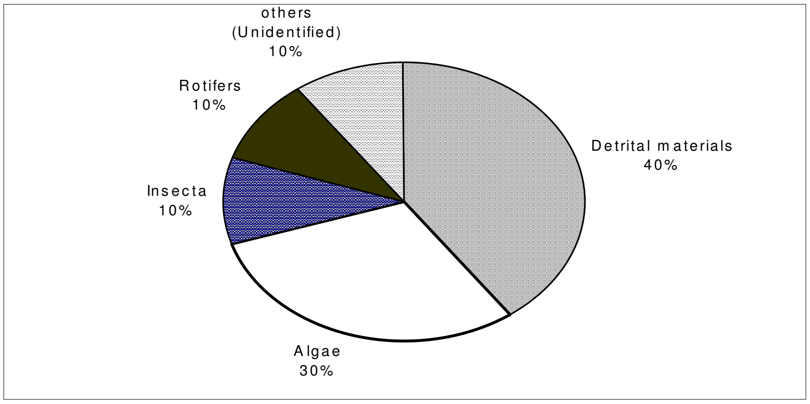

Figure 2. The composition of the gut content of *Labeo victorianus* from Kagera River.

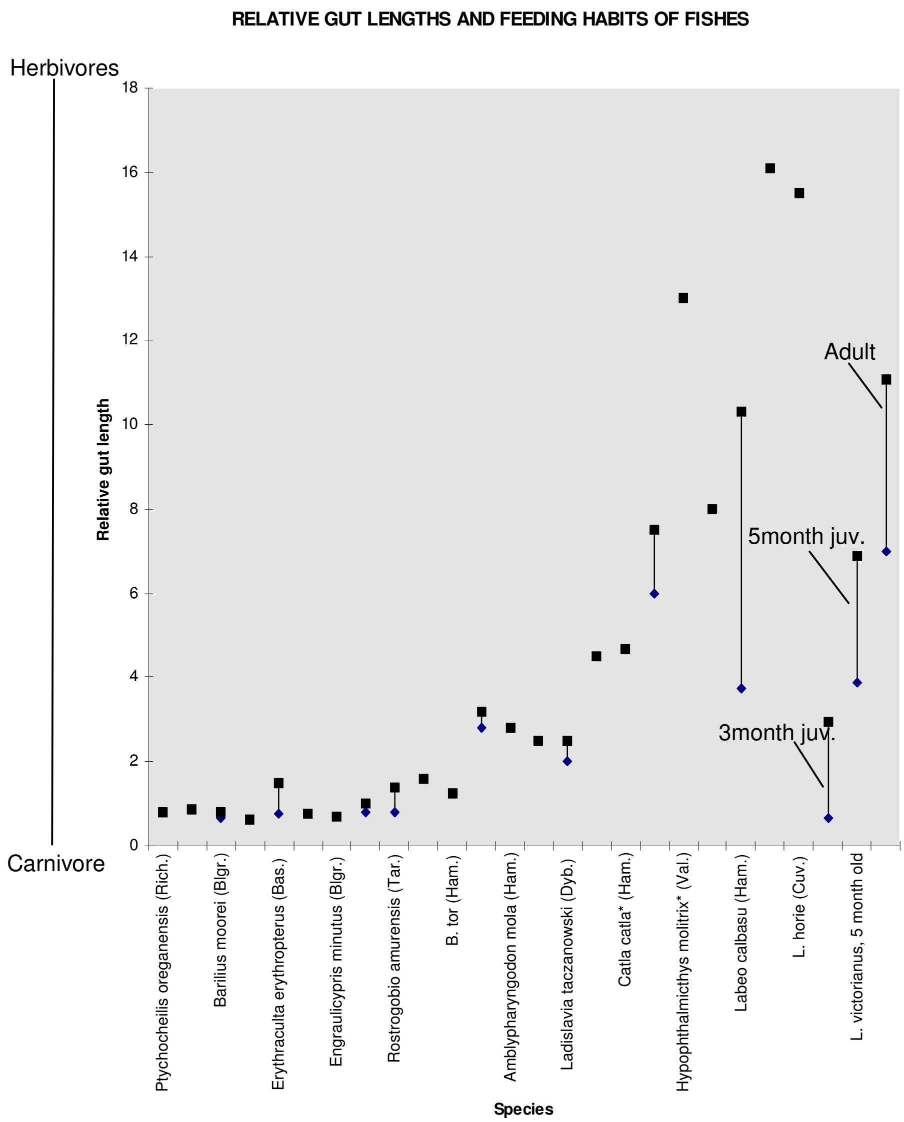

Figure 3. Relative gut length in relation to feeding habits for various fish species, including 'Ningu".

Results of the analysis of relative gut fullness (RGW) determined by the formula (weight of gut/weight of gutted fish) and relative mesenteric fat content (RFW) determined by (weight of mesenteric fat/weight of gutted fish) during an entire annual cycle indicated a clear seasonal feeding cycle in 'Ningu". Both these parameters reached peaks around the months of April and October and minima between these peaks for both the male and female fish. These periods coincide with the spawning seasons and the minima coincide with the end of spawning season (Figures 4 and 5). The peak of RFW is slightly ahead of the peaks for the RGW.

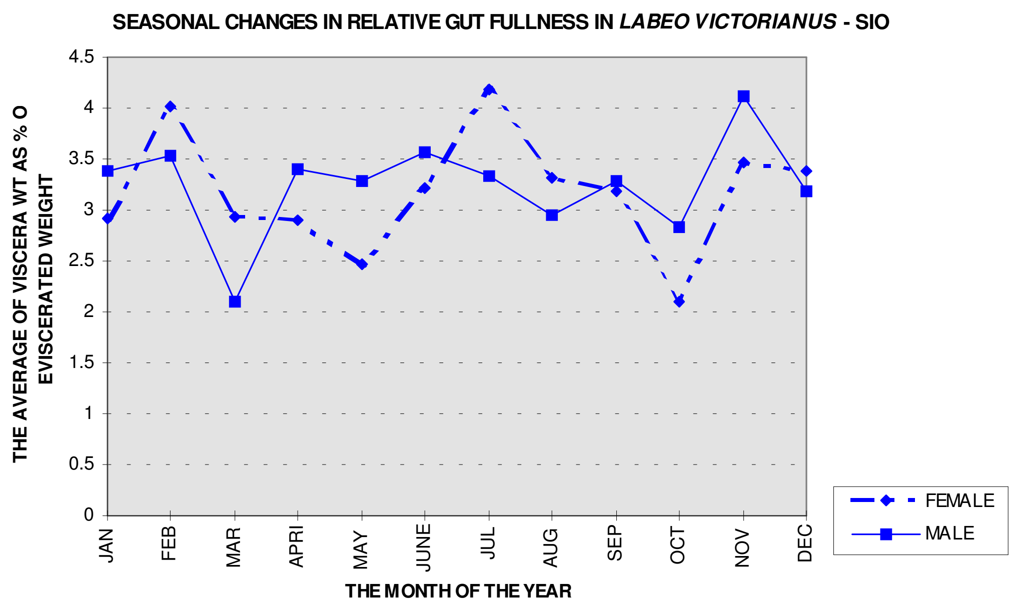

Figure 4. Seasonal changes in relative gut fullness in *Labeo victorianus* of R. Sio

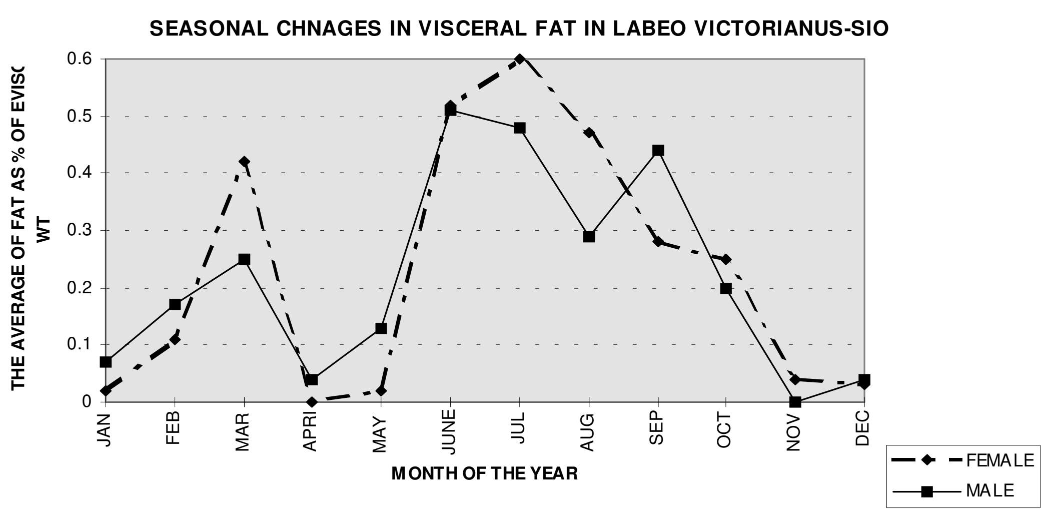

Figure 5. Seasonal changes in mesenteric fat in *Labeo victorianus* of River Sio River.

The ‘Ningu” depended on yolk sac food reserve for five to six days while the digestive system was developing for external feeding. External food in the gut of ‘ningu” was first detected on the fifth day .

Animal diet as starter food resulted in the best growth and survival for ‘Ningu” fry over either the plant diet alone or a combination of both plant and animal diet as shown in Figures 6 and 7.

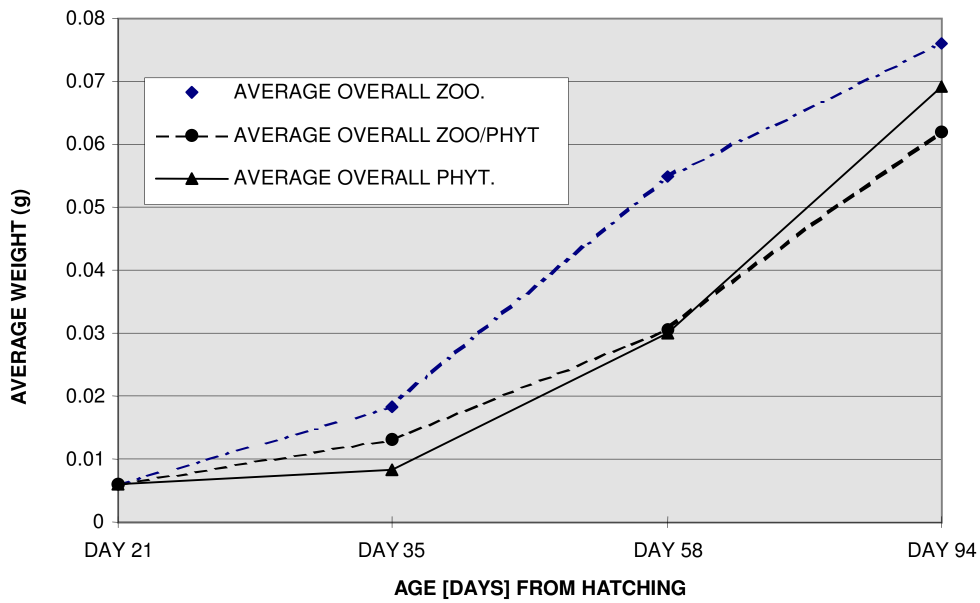

Figure 6. Impact of phytoplankton and zooplankton as starter diet on growth of *Labeo victorianus*

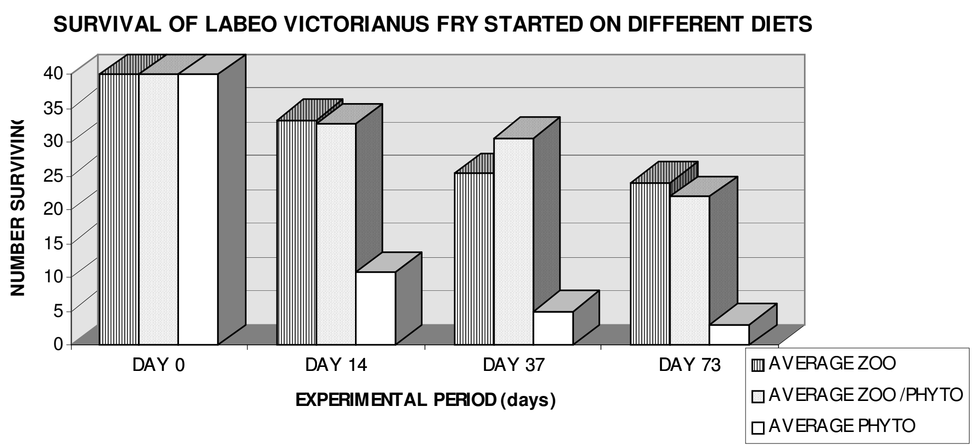

Figure 7. The impact of different starter diets on survival of juvenile “Ningu”

Both the three-week- (7.2 mm TL) and five-week-old (12.3 mm TL) juveniles were able to survive and grow on dry diet, as shown in Figure 8. The smaller juveniles, however, suffered a higher mortality in the initial stage than the larger ones (Figure 9).

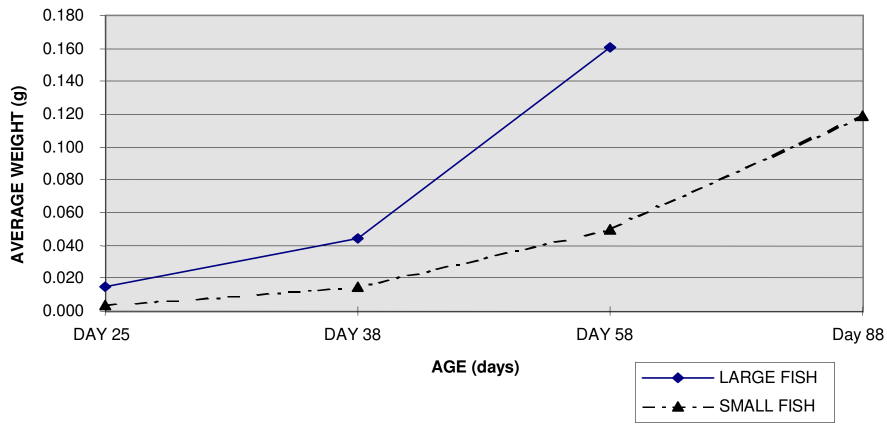

Figure 8. Growth of day old 'Ningu" juveniles on dry diet (small and big fish)

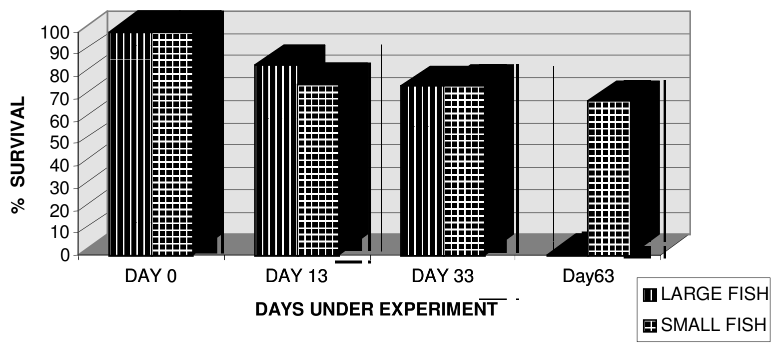

Figure 9. Survival of 25-day 'Ningu" juvenile on dry diet. (Note: all the larger fish accidentally died during the sampling on Day 33 and therefore were not available for sampling on day 63

It was gratifying to learn that the local sunflower cake treatment gave good growth and survival of 'Ningu" in ponds (Figures 10 and 11), which allowed continued observation of the feeding habits and development of the digestive system of the fish during growth.

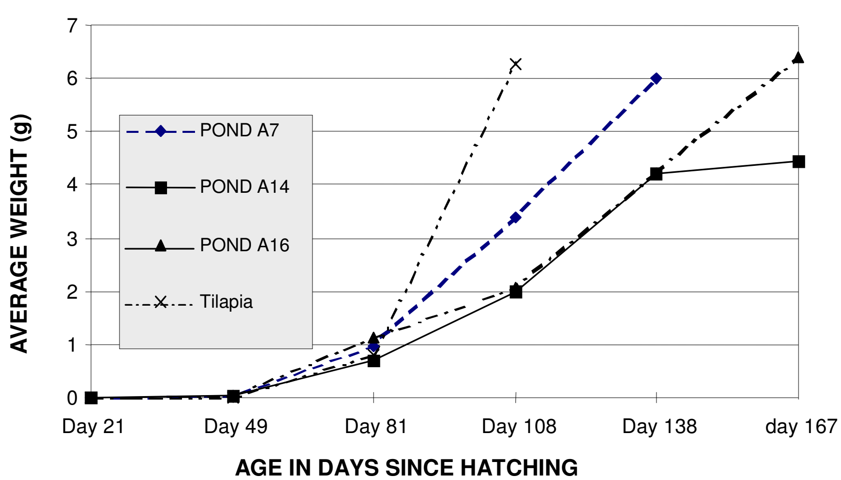

Figure 10. Growth of *Labeo victorianus* in ponds only fertilised with sunflower seed cake

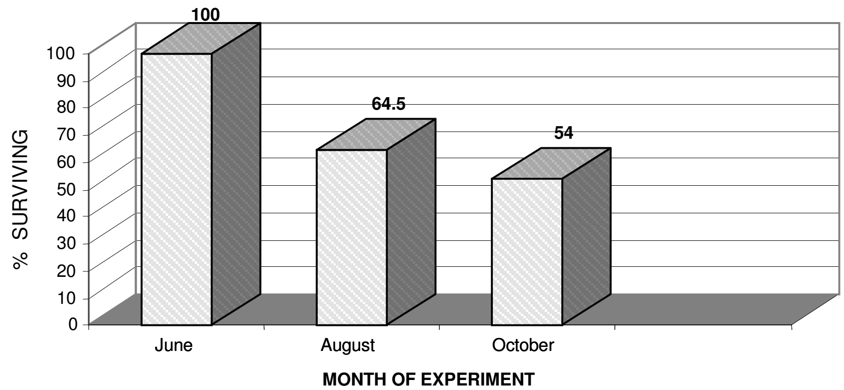

Figure 11. Survival of *Labeo victorianus* juveniles in ponds. The figures include the fish removed at each sampling for examination.

Discussion

The position and structures of the mouth of 'Ningu" are adapted for bottom feeding and for scraping epilithic materials from surfaces of submerged objects and for filtering detritus. The relatively long gut of 'Ningu" is typical of species feeding predominantly on plant diet. This further confirms the findings from analysis of the gut content of 'Ningu".

The fact that the young juvenile 'Ningu" has a relatively much smaller gut length - implying an animal diet - means that young 'Ningu" starts on animal diet and then shifts towards more plant diet as it grows. Results of starter diet using zooplankton resulted in the best growth and survival of 'Ningu".

The peaks in the relative gut fullness and relative quantity of mesenteric fat during the rainy seasons and the minima after the rainy seasons, coinciding with the spawning and recovering periods, respectively, suggests that *Labeo victorianus* feeds intensively just before, and in preparation for, spawning. Further, the fact that the peaks for mesenteric fat content are a little later on after the peaks in gut content suggests that as the spawning season approaches the food in the gut is converted into mesenteric fat as an energy store for the spawning process (Hunter and Leong, 1981; Dawson, 1986; Alheit, 1988; Kjesbu, 1989).

It is now clear that by the fifth day, when the yolk food reserve is almost exhausted, there must be adequate amount of zooplankton diet of the right size ready for the fry otherwise it starves to death. It took at least two weeks to culture reasonable quantity of rotifers. Therefore, the zooplankton culture needs to be set up at least three weeks prior to spawning of 'Ningu".

The yolk sac food reserve is not quite completely exhausted by the time the 'Nin gu" larvae starts feeding on external diet. This period of overlap helps the young fish to perfect its hunting skills and for the digestive system to become sufficiently efficient before the food reserve is completely exhausted (Pitcher and Hart, 1982).

Results of the dry feed experiments showed that 'Ningu" larvae are ready to take and utilize dry diet at 7.2 mm total length, i.e. at three weeks after hatching. This is good because the larvae of 'Ningu" can be weaned to formulated diet quite early in life and may reduce on the cost of prolonged feeding on live food.

Both growth and survival of 'Ningu" in ponds only fertilized with sunflower cake was impressive. The high survival rate (over 54%) of *Labeo victorianus* in ponds suggests that the fish will be easy to grow in ponds. The pond grown fish attained twice the average weight of 'Ningu" of the same age group in the wild (Figure 10) with just pond fertilization, despite the fact that these fish had initially been kept in glass aquaria for over two months observing development of the digestive system prior to transferring into ponds. It is possible that un-delayed transfers into ponds and supplementing fertilization with quality diet will enhance the growth rate of 'Ningu" several times over and above its growth rate in nature.

Conclusion

The fry of 'Ningu" depends on the yolk food reserve for only five days and good quality food must be supplied to the fry starting by the fifth day of age otherwise the fry starves to death. Zooplankton, especially rotifers, are the best starter food for 'Ningu" fry. After three weeks 'Ningu" fry can be fed on plant and dry formulated diet. There is now sufficient knowledge about the feeding biology of the various growth stages of 'Ningu" to allow formulation of the diets for the different stages.

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