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GROWTH PERFORMANCE OF *CLARIAS GARIEPINUS* (BURCHELL, 1822) REARED IN GLASS AQUARIA UNDER DIFFERENT LIGHT CONDITIONS

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ABSTRACT

Growth performance of Clarias gariepinus (Burchell, 1822) reared in glass aquaria under different light conditions was studied from hatching to 75 days post hatching (dph). The objective was to generate baseline data/information on artificial seed production of catfish under different rearing conditions. Eggs of C. gariepinus were hatched at three photoperiods in complete darkness (DD), full illumination (LL) and control 12 h dark and 12 h light (normal) growth conditions. African catfish showed higher survival rates in the dark conditions than in the light conditions. The larvae also showed significantly increased cannibalistic behavior under light condition. Highest survival rate (92.8%) was observed for C. gariepinus that grew under darker condition. The higher activity of C. gariepinus under dark conditions resulted in reduced rates of cannibalism and higher rates of survival than light conditions. The sequence of development and ossification was faster in dark group by a day than in the light and by two days in the control group, whereas light group faster by a day compared to the control group. Some of the organ development and appearance completed within an hour gap and it was difficult to look sequential ontogeny on dark growth conditions. Dark growth conditions may be recommended as a best, effective technique for intensification of production of C. gariepinus, as it improves catfish survival rates.

Keywords: Cannibalism, Clarias gariepinus, Glass aquaria, Ontogeny, Survival rate

1. Introduction

The African catfish, *Clarias gariepinus* (Burchell, 1822) is one of the most important species currently being farmed. It is a native species of tropical and subtropical freshwaters and has been widely farmed in heated waters outside its natural range (Hecht and Appelbaum, 1988;

Van Weerd, 1995). Its rapid growth at high densities, ability to breathe air and to withstand poor water quality, and its tasty flesh make *C*. *gariepinus* an excellent candidate for aquaculture (Appelbaum and Kamler, 2000). However, the larval rearing methods for *C*. *gariepinus* still have several problems. For instance, the larvae exhibit strong cannibalism, which results in low survival rates in hatcheries (Mukai *et al*., 2008).

According to Kamle (2000), *C*. *gariepinus* larvae and juveniles show unusual behavior. They have the ability to feed under dark conditions and can be reared under dim light or dark conditions (Appelbaum and Kamler, 2000), indicating that their behavior must be dependent on sensory organs than the eyes.

Clarias gariepinus have been reported to show photophobic behavior (Britz and Pienaar, 1992). According to Britz and Pienaar (1992), the highest growth of *C*. *gariepinus* larvae reared in continuous darkness cover as compared to larvae reared in continuous light, and territorial aggression was mitigated by darkness, but light conditions had no significant influence on larval mortality. This led to the suggestion that restriction of light may be important in *C*. *gariepinus* culture for enhancement of growth and stress reduction (Britz and Pienaar, 1992).

A number of factors need to be considered before deciding any species for use in aquaculture. The standard criteria for evaluating the aquaculture potential of species are related to a number of characteristics such as growth rate, yield and market value (Hecht and de Moor, 2005).

Many researchers have suggested small-scale commercial aquaculture for Ethiopia which is deficit in animal proteins, in particular during fasting periods (Balarin, 1986). Commercial aquaculture in Ethiopia is still at infant stage in spite of the fact that the country's physical and socio-economic conditions favor its development. To this end, the country developed a national aquaculture development strategy since 2009 to enhance the aquaculture production.

The lack of fry, failure to breed in ponds and absence of previous experience on catfish rearing in the country as a whole have been the main constraints for effective breeding of this species. In 2012, an attempt was made on rearing of African catfish at Bahir Dar Fisheries and Other Aquatic Life Research Center. It was performed successfully at experimental level on artificial rearing and seed production of *C*. *gariepinus*. The situation paved the road for propagating *C*. *gariepinus* artificially. However, such work requires significant technical back up in terms reduction of larvae mortality, survival rate and developmental ontogeny, which are lacking. Thus, the purpose of the study is to examine the effect of light on survival rates and developmental ontogeny of *C*. *gariepinus* under culture conditions. This work will therefore serve as a springboard to fulfill the necessary data and fill gaps needed for future catfish farming in the country.

2. Materials and Methods

Fertilized eggs were obtained by hormone-induced *C*. *gariepinus* brood stock originating from Lake Tana which were kept indoor glass aquaria at Bahir Dar Fisheries and Other Aquatic Life Research Center. Artificial spawning was induced by hypophyzation which involved the injection of two female fishes (weight: 1-2 kg).

Female fish were injected pituitary homogenate in the afternoon between 18:00 and 19:00 and placed in covered glass aquaria containing fresh and oxygenated water for 14 h. At 08:00 am the following morning, the female fishes were removed from the tanks for stripping of eggs.

Two mature male fishes (weight: 1-2 kg) were subsequently anaesthetized and their testes were removed using a pair of forceps. The semen was added to the eggs within 30 seconds after removal of the testes and was gently mixed with the eggs using a soft rubber spatula and feather. A small quantity of water was added which made the eggs swell and adhesive. Stirring and adding of water was done continuously for five minutes. The fertilized eggs from pooled spawn (72 g) were weighed and used for the experiment.

2.1. Experimental design

Three groups of embryos and yolk feeding larvae were simultaneously incubated. One group was incubated under full light (the L-group) which were continuously illuminated by artificial light (40 W fluorescent tube) over each tank (natural and artificial light, 24 h) and the second kept in a complete darkness (the D-group) in which the glass aquaria were covered with black plastic sheets. The third group was left in glass aquaria for natural fluctuation of light and dark (control group). At the end of yolk feeding four experimental and a control group were set (triplicate glass aquaria per group), according to the different light and dark conditions.

The fifteen glass aquaria rearing tanks (35 x 30 x 18 cm, 25 L water in each) were coded as LL1, LL2, LL3, LD1, LD2, LD3, DL1, DL2, DL3, DD1, DD2, DD3, N1, N2 and N3. The first letter (L or D) denotes light or dark conditions during egg incubation and larval endogenous feeding. The second letter indicates the conditions during exogenous feeding (we switched to light or dark condition to see larval performance difference during exogenous feeding in relation to its hatching condition). Letter N indicates the control group in which from egg incubation until the end of the experiment then stay in natural fluctuation of light and dark and number 1 or 3 denotes the triplicate.

Each aquarium was provided with oxygen by electrical aerator through an air stone attached to it, and with UV treated and filtered lake water from the re-circulation system. Rearing temperature was adjusted to 29.0°C using an electrical thermo regulating system according to Verreth and Den Bieman (1987) as the optimum recommended temperature for *C*. *gariepinus* larval rearing.

Food was first offered to the larvae at age 3.88 days post-fertilization (2.73 days post hatching). Larvae were hand fed in excess every 5 h with newly hatched *Artemia nauplii* (imported *Artemia* cyst) for the first 6 days, then they were gradually, over 4 days weaned to dry feed (Aqua Nutro Pre Starter 00). After weaning, dry feed offered in excess two times a day 9 am at morning and 5 pm in the afternoon on which they were kept until the end of the experiment. Waste was siphoned from each aquarium and water was added daily. In case of power interruption a stand by generator was available. The experiment lasted 75 days to avoid competition for space and disease occurrence due to small size of the aquaria.

2.2. Ontogenesis

Observations of larval ontogenetic advancement, pigmentation and behavior were carried out several times per day. Survival rates were assessed at 3.8, 14, 19, 24, 29, 34 and 40 days post-fertilization. This was done by removing all fishes from each tank and then counting the fish. Prior to removing the dark-reared group fish were exposed to light for 20 minutes to avoid stress. Fish sampled for analysis were accounted for cranial bones (the cannibalism left-overs) were removed daily and counted.

The study of ontogenic development was conducted using differential staining of cartilage and bone staining (alcian blue and alizarin red S) fins and stained according to Walker and Kimmel

(2007). Identification of body structure was made based on Adriaens and Verraes (1997) and Belay Abdissa (2009).

2.3. Larvae fixation and double staining

The specimens were fixed in 10% neutral formalin solution and stained using acid-free double stain methods (Walker and Kimmel, 2007). The stained larvae were photographed with a light microscope (Olympus SZ40) with Sony model DSC-W320 digital camera mounted on the eye pieces. Photos of bigger live fish were taken from the treatment aquarium using specially made photographing aquaria with the same digital camera used above.

The length of the larvae measured with a dissecting microscope ocular meter attached on eye pieces and digital caliper to the nearest 0.01 mm. When the larvae length increased ichthyometer (measuring board) was used until 75 dph. For assessment of the degree of skeletal development, the numbers of the stained vertebrae were counted under a light microscope.

2.4. Sampling

Sample specimens were taken from fertilization until 75 dph. Immediately after fertilization, 5 sample eggs were taken from the two experimental and control group every hour until hatching. After hatching, sampling was done every eight h till yolk absorption (4 dph). When the larvae were transferred to experimental set up (LL, LD, DL, DD and N) and started exogenous feeding, sampling was made every day until 30 dph. Then after sampling continued every fortnight till last day 75 dph using measure and put back again method. The above measured and put back again techniques used in order to follow the length and weight change through the rest of the experiment period due to small number of sample available.

2.5. Data analysis

Data analysis was made using Statistical Package for Social Science Students (SPSS Inc., software version 20.0) and Microsoft Excel 2010. For normally distributed data, one way ANOVA were used to analyze the variations in survival and growth rates between the different groups.

3. Results

3.1. Ontogenesis

Hatching of the incubated eggs started at the age of 19 hr. post-fertilization. Three hours later (age 22 h), 50% of individuals had hatched; 85% of them had hatched at the age of 24 h. The transition from an embryo developing within an egg to a yolk-feeding larva was clearly observed at the age of 22 h after fertilization. The newly hatched larvae of the two experimental group L-group, D-group and the control N-group with (5.5±0.2, 5.7±0.1 and 4.8±0.5 mm) total length (TL±S.E, n=5) were observed at the bottom of the aquaria, respectively. One day-old yolk-feeding larva of the two experimental groups: L-group (6.5±0.2 mm), D-group (6.7±0.2 mm) and the control group (6.6±0.1 mm) moved continuously at the bottom of the aquaria and sometimes swam vertically and horizontally in the middle layers of the water column.

Three-day old larvae of the two experimental L-group (7.2±0.3 mm), D-group (8.4±0.1 mm) and control group (8.1±0.2 mm) commenced feeding on *Artemia* and artificial compound feed, under light, completely dark and a control natural fluctuation of 12 h, light and 12 h dark conditions.

Larvae swam most often at the bottom, in contact with the bottom substrate of the aquaria and against the water turbulent of the aeration.

Three day-old larvae of the two experimental and control group (7.2±0.3, 8.4±0.1 and 8.1±0.2 mm) displayed cannibalism such that when larvae rested at the bottom of an aquarium, other individuals bite the resting larvae.

Six day-old larvae of the two experimental and control group (9.7±0.1, 9.8±0.1 and 9.0±0.2 mm) swam mostly at the bottom of the aquaria and sometimes in the middle and surface layers at daytime. They swam throughout the surface and middle layers more actively at night time under dim light conditions, then cannibalistic behavior was not severe as in the light conditions.

Seven-day-old larvae of the two experimental and control group (10.5±0.1, 11.1±0.1 and 9.6±0.2 mm) exhibited distinguishable resting behavior under light conditions; they suddenly stopped moving and appeared unconscious under light conditions (Plate 1). This behavior continued until they were 40 days old, at the final day of observation. The fish displayed higher activity in the dark, thus resting behavior was less prevalent in the dark than the light condition. The behavior of older stage (up to 40-day old) larvae was similar to 7-day old larvae.

Plate 1. Discriminative resting behavior of *C*. *gariepinus* in light conditions (arrow indicate unconscious display of fish) (Photo credit Seble Getahun).

3.2. Survival

Cannibalism was first observed at the age of 7.5, 6.6 and 8.1 days post-hatching of LL, DD and N growth conditions, respectively. Catfish of average length of about 10.5, 9.8 and 8.3 mm at LL, DD and N growth conditions were found to have been attacked by others of similar sizes. The attacks were first carried out at tail. In the course of the experiment, fish carrying signs of attacks (body damages) were found. In our study, it was at 18 days post-hatching (dph) that a pronounced cannibalistic behavior was observed on DL, DD, and LD with % value of 2.33, 1.5, 1.33 and 0.67 for both LL and N growth conditions, respectively (Table 1). On the 33 dph, the highest cannibalistic behavior recorded for DL, N and LL with value of 3.67, 2.16 and 0.67%, respectively whereas the DD and LD scored the lowest value of 0.33% each. The overall cannibalistic behavior showed that the growth conditions of DL scored the highest 17.5%,

followed by 4.85% of N, 4.24% of LL and lowest score of 2.27% DD and 2.15% of LD growth conditions (Table 1).

Table 1. Cannibalistic occurrence under different growth condition and growth period (Mean ± S.E).

Day	**LL**	**LD**	**DD**	**DL**	**N**	Remark
4 dph	0	0	0	0	0	Yolk absorption
18 dph	0.67±0.2	1.33±0.4	1.5±0.3	2.33±1.8	0.67±0.2	2nd observation
23 dph	0.33±0.2	0	0	0.36±0.3	0.16±0.2	3rd observation
28 dph	0.33±0.2	0	0	0.5±0.3	0	4th observation
33 dph	0.67±0.2	0.33±0.2	0.33±0.3	3.67±2.7	2.16±0.6	5th observation
40dph	1.77±0.5	0.33±0.2	0.33±0.3	1.73±0.7	1.33±0.9	6th observation
Total	4.24±0.8	2.15±0.2	2.27±0.6	17.5±5.7	4.85±1.9	

Larvae transferred from the dark incubation to light growth conditions DL showed lowest survival rate which was preceded by LL, N, and DD gradually with highest survival rate of LD growth conditions.

Survival decreased in the sequence LD, DD, N, LL and DL (Table 2). The final survival of juveniles varied from 85.0% to 92.8% (Table 2) at different treatments. At the 14 and 19 dph, the LL and N growth condition had high individual survivor as compared to the dark group DD and LD including a light growth condition DL that transferred from dark incubation. At 24 dph, N growth condition had highest survivor whereas LL and both dark group DD and LD had equal survivor and the DL growth conditions exhibit lower individual survivor. From 29 dph upto the last of the experiment 40 dph, both the dark group LD and DD had high number of survivor next the N growth condition whereas the light growth conditions shows lower individual survivor especially DL with small survivor even in comparison with the light-group growth condition LL (Table 2). Significant differences were found in all the comparisons (Table 2), suggesting that survival rate was depressed not only by rearing in light conditions during external feeding (LL<DD, LL<N, DL<DD, N<DD, DL<LD, DL<N, N<LD and LL<LD) but also exposure to light during yolk-feeding period had a negative effect on survival of juveniles later on (DL<LL and LD<DD).

Table 2. Survival of *C*. *gariepinus* juveniles aged 14-40 days (Mean±S.E).

Growth	**Age (day)**					**Survival (%)**
conditions	**14**	**19**	**24**	**29**	**40**	
LL	198.7±0.3	198±0.6	197±1.2	195.7±1.2	192.7± 1.5	85.5±0.8
DL	195.3±3.7	195±4.0	19 4±4.0	186.7±6.2	183.7± 7.2	85.0±3.8

DD	197±0.6	197±0.6	197±0.6	196.3±0.9	195.7± 1.2	92.8±0.7
LD	197.3±0.9	197.3±0.9	197.3±0.9	197.7±0.9	197± 0.6	86.5±3.2
N	198.7±0.3	198.3±0.3	198.3±0.3	194±1.5	191.3± 3.2	85.6±0.3

3.3. Larval and post-larval development

The one day post hatched larvae were transparent and faintly brown in color and had an average length 5.7±0.1, 5.5±0.2 and 4.8±0.5 mm for the three growth conditions DD, LL and N, respectively with a laterally compressed body. The head and the yolk sac together appeared as a bulb-like structure when viewed from above. Dark pigmented and prominent eyespot appeared on the anterior part of the head. The buccal invagination appeared and it was not connected with the pharyngeal tube. The upper jaw and lower jaws were formed. A thin membranous fin fold (sheath) surrounded the caudal region and extended up to the yolk sac (Plate 2a). The anal fin fold around the tail was continuous. The pectoral fin buds were seen as a small protuberance, and the alimentary tract was distinct. The mouth was not yet opened at this stage and the anal opening was still closed. The heart was seen in front of the yolk and the blood circulatory system was fully functional (Plate 2a). By the time of hatching, larvae of *C. gariepinus* do not have any bones on the skull. All specimens examined at 24 h old larvae had cartilaginous elements of the parasphenoiduim (PS) and ossified cleitrum (CLT), operculum (OP), vomer (VO) and lacrimale (LC) which were the first to appear. Barbels appeared in the form of tiny knobs in one day old larvae (Plate 2b).

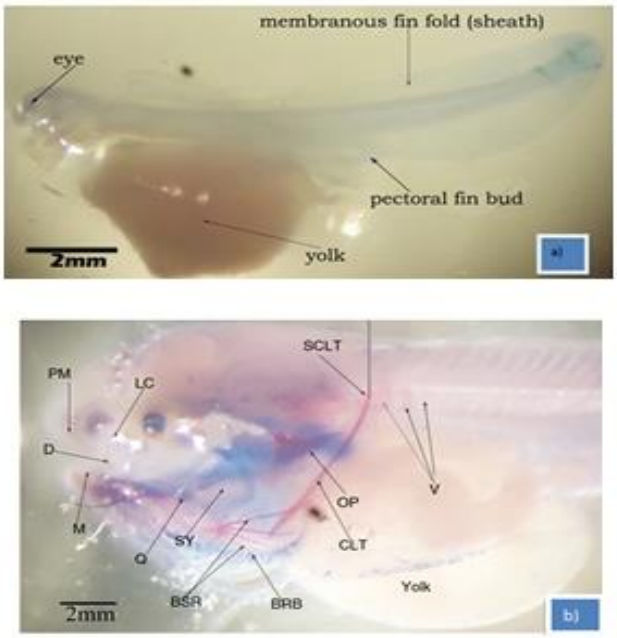

Plate.2. Alcian blue and alizarin red stained *C. gariepinus*. a) 24 h old larva (1 dph). Magnification 40 X, b) Lateral view of chondrocranium (2 dph).BRB, barbell; BSR, branchiostegal rays; CLT, cleitrum; D, dentale; LC, lacrimale; M, maxilla; OP, operculum; PM, premaxilla; Q, quadratum; SCLT, subcleitrum; SY, symplecticum; V, vertebrae.

In 2 dph, larva attained an average length of 7.2±0.1 mm. There is addition of new bone, the cartilaginous subcleitrum (SCLT), interoperculum (IOP), suboperculum (SOP), quadratum (Q),

palatinum (P), entopetrygrydium (ENPT), articulare (A), retreoarticulare (RA), metpetrygrydium (MPT), hyomandibulare (HM) and ossified maxilla (M), premaxilla (PM), dentale (D), five branchiostegal ray (BSR), operculum (OP), simplicticum (SY) and three vertebrae appeared anteriorly near the base of the head (Plate 2b).

3.4. Developmental ontogeny of *C. gariepinus* reared at dark growth conditions

3.4.1. Day 3 and day 5 post–hatching *C. gariepinus*

In all specimens examined at 3 dph, hyoideium (HY), hypohyale (HH), uratohyale (URH), articulare (A) and retreoarticulare (RA) were ossified. Cleitrum (CLT) fused with coracodium (COR) and as compared to the 2 dph the number of branchiostegal rays (BSR) became eight at 3 dph and finalized its number to nine at 4 dph. The quadrato-mandibular joint appears at 4 dph and the hyomandibulo-opercular joint at 5 dph (Plate 3a). Four ossified caudal fin rays (CFR) appear for the first time at 3 dph with parhypurale (PH) and three cartilaginous hypurale (HU) (Plate 3b) and also additional five ossified vertebrae (V). At 5 dph the caudal region had a total of ten caudal fin rays (CFR) and 23 vertebrae (V). In the head region sub operculum (SOP) and simplicticum (SY) got ossified at 4 dph whereas at 5 dph ossification of hyomandibulare (HM), quadratum (Q), epihyale (EH) and two pectoral fin rays (PFR) occurred and II ceratobrachial appeared.

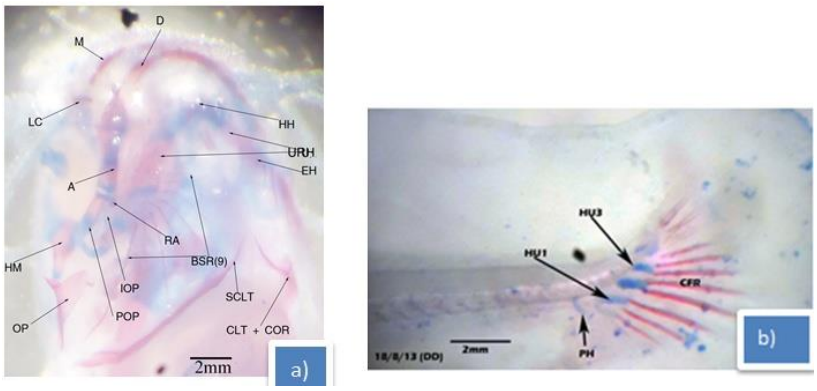

Plate 3. Alcian blue and alizarin red stained *C. gariepinus* (5 dph) a) Ventral view of neurocranium, b) Lateral view of caudal fin. A, articulare; BSR, branchiostegal ray; CLT, cleitrum; CFR, caudal fin ray; COR, coracoid; D, dentale; EH, epihyale HH, hypohyal; HM, hyomandibulare; HU, hypurale; IOP, interopercle; LC, lacrmale; M, maxilla; OP, opercle; PH, parahypurale; POP, preopercle; RA, retroarticularis; SCLT, subcleitrum; URH, uratohyale.

3.4.2. Day 15 and day 20 post–hatching *C. gariepinus*

At 15 dph larva measured an average of 20.7±0.3 mm. At this stage, organogenesis was completed and the juveniles were morphologically similar to the adult with 25 caudal fin rays (CFR) consisting of closely connected hypurals (1-5), enlarged neural spine (ENS) and epural (EP) originated from the second pleural centrum (PU2), and 64 dorsal fin rays (DFR) and 51 anal fin rays (AFR) of which the base was not ossified (cartilaginous). In the case of vertebrae, all were ossified and had neural and hemal spines (Plate 5.6a). In the head region, all of the organ development was completed and the last ossified was hyoid bar and all the five

ceratobranchial (CBRI-V) were present. The supracleithrum (SCL) were added to the pectoral girdles (Plate 4b).

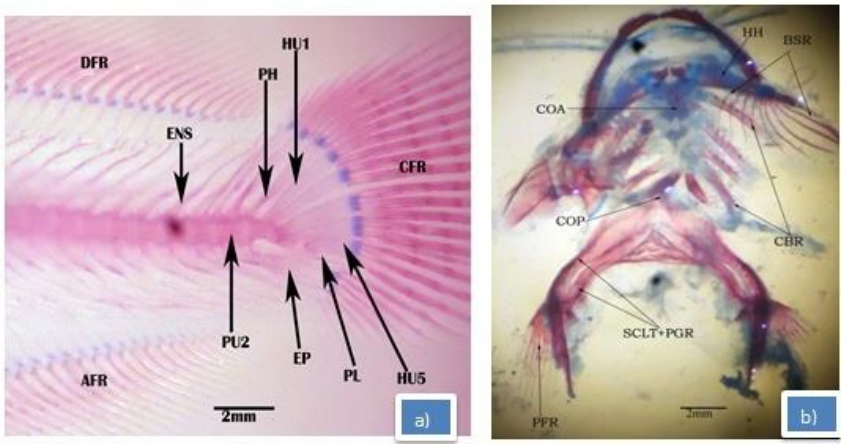

Plate 4. Alcian blue and alizarin red stained *C. gariepinus* (15 dph).a) Lateral view of dorsal, anal and caudal fin, b) Ventral view of head region. AFR, anal fin rays; BSR, branchiostegal ray; CFR, caudal fin rays; COA, copula anterior; COP, copula posterior; CBR, ceratobranchial (I-V); DFR, dorsal fin rays; ENS, elongated neural spine; EP, epurale; HH, hypohyal; HU1, first hypurale; HU5, fifth hypurale; PFR, pectoral fin rays; PH, parahypurale; PL, pleurostyle; PU2, second preural centrum; SCLT+PGR, supracleitrum + pectoral girdle (CPG, coracoid of pectoral girdle).

The average length of 20 dph larva were 23.62±0.67 mm. Compared to the 14 dph, significant changes were noticeable in 20 dph larva. At this stage all of the skeletal parts added to the head region are fully ossified. Most of the bones were fused and reduced in number (Plate 5a - c).

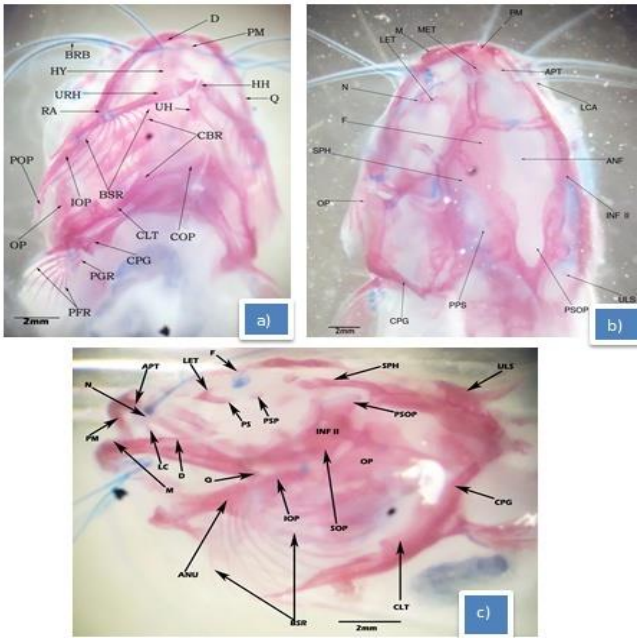

Plate 5. Alcian blue and alizarin red stained *C*. *gariepinus* (20 dph). a) Ventral view of neurocranium, b) Dorsal view of the head region. c) Lateral view of chondrocranium (28 dph). ANF, Anterior fontanel; ANU, Angulare; APT, Autopalatine; BRB, barbell; BSR, branchiostegal ray; CBR, ceratobranchial; CLT, cleitrum; COR, Coracoideum; CPG, coracoid of pectoral girdle; D, dentale; ECPT, ectopetrygrydium; ENPT, entopetrygrydium; F, frontale; HH, hypohyal; HM, hyomandibula; HY, hyoideum; ICO, intercolare; INF II, Infra orbital II; Inf4, Infra orbital4; IOP, interopercle; K, kinethmoidum; LC, lacrimale; LCA, Lacrymal antorbital; LET, lateralethmoideum; M, maxillas; MET, Mesethmoid; MPT, metapetrygrydium; N, nasale; NR, neris; O, orbital; OP, opercle; OSP, orbitosphenoideium; PFR, pectoral fin rays; PGR, Pectoral girdle; PM, premaxilla; POP, preopercle; PR, parietale; PS, parasphenoideum; PSOP, Purieto supraoccipitale; PSP, petrosphenoideum; POT, postemporale; Q, quadrate; RA, retroarticularis; SCLT, subcleitrum; SOB, supraorbitale; SOP; SPH, Sphenotic; SUP, supraoccipitale; SY; symplecticum; UH, urohyal; ULS, Upper lateral scute; URH, uratohyale; VO, vomer.

3.4.3. Day 75 post–hatching *C. gariepinus*

Plate 6 shows a grown catfish at 75 dph with full structural development. The average length of the 75 dph old larvae was about 133.6±6.7mm and it was dark in color.

Plate 6. Grown *C*. *gariepinus* in dark condition (75 dph).

3.5. Developmental ontogeny of *C. gariepinus* reared at light growth condition

3.5.1. Day 3, day 4 and day 5 post–hatching *C. gariepinus*

The 1 dph larvae were transparent and faintly brown in color and 6.6±0.1 mm in length with a laterally compressed body. The hatchlings had unpigmented eyes and were devoid of distinct mouths and fins. Since the head was very small, it was not distinctly separated from the yolk sac. The yolk sac was oval in shape and pale greenish in color. The diameter of yolk sac was 0.65 mm. A functional heart with blood circulation was noticed. The head and the yolk sac together appeared as a bulb-like structure when viewed from above. The fin folds were differentiated as a thin membranous fin fold surrounded the caudal region and extended up to the yolk sac (Plate 7). And the anal fin fold around the tail was continuous. The larvae inhabited the bottom of the tank and swam with rapid movements using their tails.

The average length of the 2 dph larvae was about 6.7±0.2 mm. At 2 dph the larvae have a cartilaginous element of dentale (D), articulare (A), retreoarticulare (RA) and quadratum whereas an ossified element of a thin thread-like cleitrum (CLT), a triangular shaped operculum (OP) lacrmale (LC) and a single branchiostegal ray (BSR) appeared for the first time. After six hours, additional four branchiostegal rays (BSR) were observed (Plate 8).

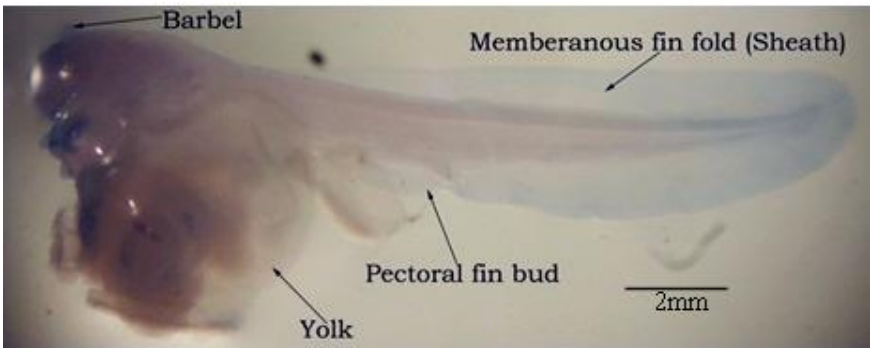

Plate 7. Alcian blue and alizarin red stained *C*. *gariepinus* 1 dph larva. Magnification 40 X

All specimens examined at 3dph had an ossified element previously appear at 2 dph. These were subcleitrum (SCLT), maxilla (M), premaxilla (PM), quadratum (Q), uratohyale (URH), hypohyale (HH), additional five branchiostegal ray (BSR), ten vertebrae (V), and cartilaginous elements of the suboperculum (SOP), palatinum (P), simplicticum (SY), entopetrygrydium (ENPT), ectopetrygrydium (ECPT), hyomandibulare (HM) and epihyale (EH) which are the first to appear on the head region. In the caudal region, five caudal fin rays (CFR) arise on three cartilaginous hypurale.

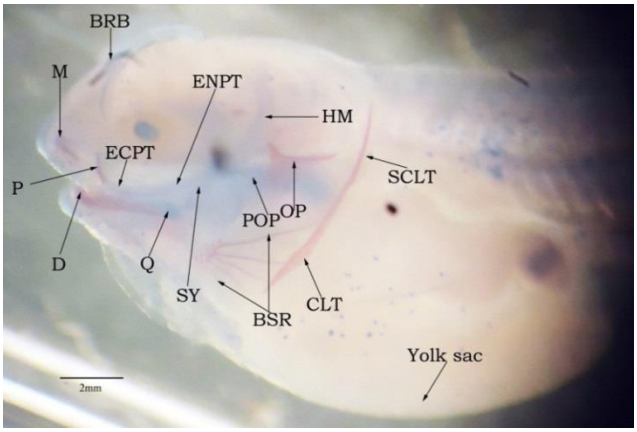

Plate 8. Alcian blue and alizarin red stained *C*. *gariepinus* (3 dph) (Lateral view of chondrocranium). BRB, barbell; BSR, branchiostegal ray; CLT, cleitrum; D, dentale; ECPT, ectopetrygrydium; ENPT, entopetrygrydium; HM, hyomandibulare; M, maxilla; OP, operculum; P, palatinum; Q, quadratum; SCLT, subcleitrum; SY, simplicticum.

3.5.2. Day 20 post–hatching *C. gariepinus*

At 20 dph ossified neural arches of terminal vertebra (NA), urostylar (UR), enlarged neural spine (ENS), pleurostylar (PL), second preural centrum (PU2) which bear epural (EP) and vertebra (V) were present in the caudal region (Plate 9).

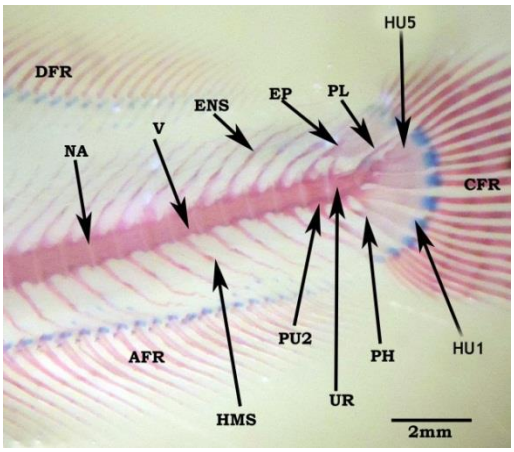

Plate 9. Alcian blue and alizarin red-stained *C*. *gariepinus*. Lateral view of caudal fin (20 dph). AFR, anal fin rays; CFR, caudal fin rays; DFR, dorsal fin rays; ENS, enlarged neural spine; EP, epural; HMS, hemal spine; HU1, first hypurale; HU5, fifth hypurale; NA, neural arches; PH, parhypurale; PL, pleurostylar; PU2, second preural centrum; UR, urostylar; V, vertebrae.

3.5.3. Day 23 post–hatching *C. gariepinus*

The average lengths of 23 dph larva were 21.98±0.46 mm. Compared to the 17 dph, significant changes were noticeable in 23 dph. At this stage all of the skeletal parts added to the head region are fully ossified. Most of the bones were fused and reduced in number of elements (Plate 10a-c).

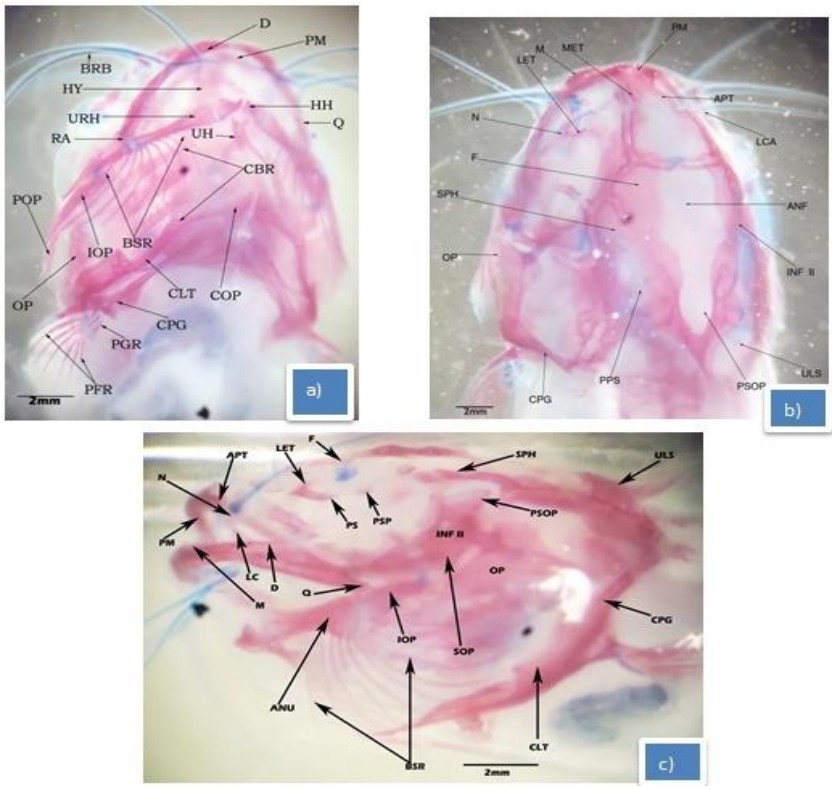

Plate 10. Alcian blue and alizarin red-stained *C. gariepinus* (23 dph). a) Ventral view of chondrocranium, b) Dorsal view of the head region, c) Lateral view of chondrocranium. ANF, Anterior fontanel; APT, Autopalatine; BRB, barbell; BSR, branchiostegal ray; CBR, ceratobranchial (I-V); CLT, cleitrum; COP, copula posterior;CPG, coracoid of pectoral girdle; D, dentale; F, frontale; HH, hypohyal; HM, hyomandibula; HY,hyoideum; INF II, Infra orbital II; IOP, interopercle; LC, lacrimale; LCA, Lacrymal antorbital; LET, lateralethmoideum; M, maxillas; MET, Mesethmoid; N, nasale; OP, opercle; PFR, pectoral fin rays; PGR, pectoral girdle; PM, premaxilla; POP, preopercle; PS, parasphenoideum; PSOP, Purieto supraoccipitale; PSP, petrosphenoideum; Q, quadrate; RA, retroarticularis; SPH, Sphenotic; UH, urohyal; ULS, Upper lateral scute; URH, uratohyale.

3.5.4. Day 75 post–hatching *C. gariepinus*

A grown catfish at 75 dph had full structural development (Plate 11). The average length of the 75 dph old larvae was about 135.2±4.6 mm and yellowish in color.

Plate 11. Grown *C*. *gariepinus* in light condition (75 dph).

3.6. Developmental ontogeny of *C. gariepinus* reared at normal growth condition

3.6.1. Day 2, day 3, day 5 and day 6 post–hatching *C. gariepinus*

The average length of the 24 h old larvae was about 6.6±0.1 mm. In all *C*. *gariepinus* larvae reared at normal growth conditions (N) of 2 dph specimens examined, the head region consists of ossified cleitrum, operclulum, premaxilla and a single branchiostegal rays; after 6 h, ossified subcleitrum, dentale and lacrimale were added. In another 6 h time un-ossified articulare, retroarticulare, quadratum, urohyale and three additional structures appeared. At 3 dph the previous cartilaginous and a newly ossified structure were seen on the head region: these are articulare, quadratum, urohyale epihyale, hypohyale, uratohyale, suboperclum, maxilla, extra five branchiostegal rays and 12 vertebrae, whereas cartilaginous structure ectopetrygrydium, entopetrygrydium, metapetrygrydium, hyomandibulare and three hypurale were added. On the same day within the next 12 h an ossified two branchiostegal rays and 7 vertebrae were added which made the number of branchiostegal rays eight, and the number of vertebrae 19 and four caudal fin rays appeared for the first time (Plate 12a and b).

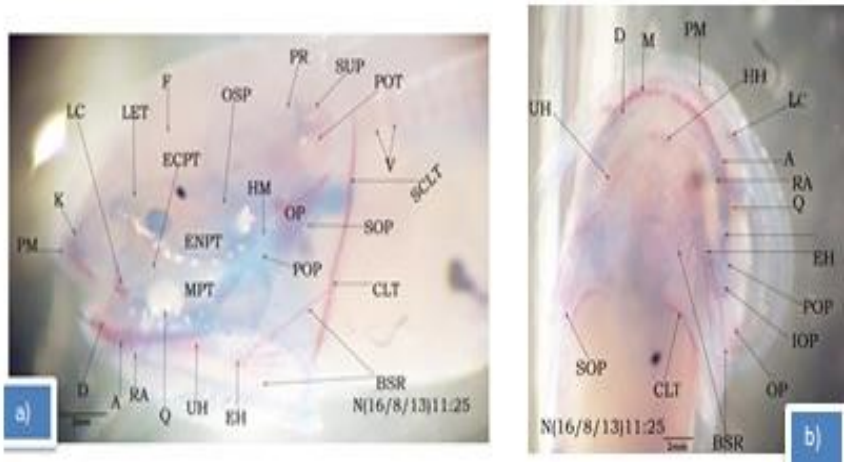

Plate 12. Alcian blue and alizarin red stained *C*. *gariepinus* (3 dph). a) Lateral view of chondrocranium, b) Ventral view of the neurocranium. A, articulare; BSR,

branchiostegal ray; CLT, cleitrum; D, dentale; EH, epihyale; ECPT, ectopetrygrydium; ENPT, entopetrygrydium; F, frontale; HM, hyomandibulare; HH, hypohyal; IOP, interoperculum; K, kinethmoidum; LC, lacrmale; LET, lateralethmoideum; M, maxilla; MPT, metapetrygrydium; OP, operculum; OSP, orbitosphenoideium; PM,premaxilla; POP, preoperculum; POT, postemporale; PR, parietale; Q, quadratum; RA, retreoarticlare; SCLT, subcleitrum; SOP, suboperclum; SUP, supraoccipitale; UH, uratohyale.

The diagrammatic view allows a complete and detailed picture of the 6 dph old *C*. *gariepinus* head region to be obtained (Plate 13a). Compared to the previous stage (Plate 13b), significant changes were noticeable at 6dph, the hyoideium, interoperculum, retreoarticulare, hyomandibulare, subcleitrum and vomer were formed in the head region. At this stage, the cleitrum were fused with coracodium. The caudal fins comprise of five ossified rays with cartilaginous parahypurale, three hypurale and hemal spine (Plate 13c).

3.6.2. Day 8 and 20 post–hatching *C. gariepinus*

The average length of the 8 dph larvae was about 10.46±0.15 mm. At 8 dph age, a number of new bones were added. These are 14 dorsal fin rays (DFR), neural spine (NS), four pectoral fin rays (PFR), four ceratobranchial (CBR), 14 caudal fin rays (CFR) and 52 fully ossified and 10 partial ossified vertebrae equipped with elongated neural and hemal spine. At 20 dph ossified neural arches of terminal vertebra (NA), urostylar (UR), enlarged neural spine (ENS), pleurostylar (PL), second preural centrum (PU2) which bear epural (EP) and vertebra (V) was present in the caudal region (Plate 14).

Aquaponics

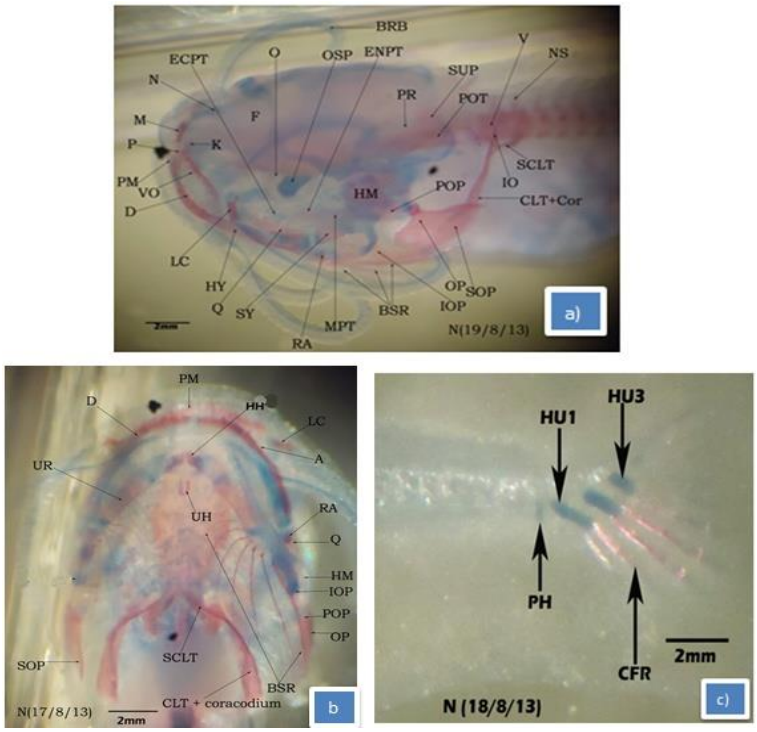

Plate 13. Alcian blue and alizarin red stained *C*. *gariepinus*. a) Lateral view of chondrocranium (6 dph), b) Ventral view of neurocranium (4 dph), c) Lateral view of dorsal fin (5 dph). A, articulare; BRB, barbell; BSR, branchiostegal ray; CLT, cleitrum; CFR, caudal fin ray; COR, coracoid; D, dentale; ECPT, ectopetrygrydium; ENPT, entopetrygrydium; F, frontale; HH, hypohyal; HM, hyomandibulare; HMS, hemal spine; HU, hypurale; HU1, first hypurale; HU3, third hypurale; HY, hyoideum; IO, intercolare; IOP, interopercle; K, kinethmoidum; LC, lacrmale; M, maxilla; N, nasale; NS, neural spine; OP, opercle; OSP, orbitosphenoideium; P, platinum; PH, parhypurale; PM, premaxilla; POP, preopercle; POT, postemporale; PR, parietale; Q, quadratum; RA, retroarticularis; SCLT, subcleitrum; SOP, suboperclum; SUP, supraoccipitale; SY, symplecticum; UH, urohyale; UR, uratohyale; ULS, Upper lateral scute; V, vertebrae; VO, vomer.

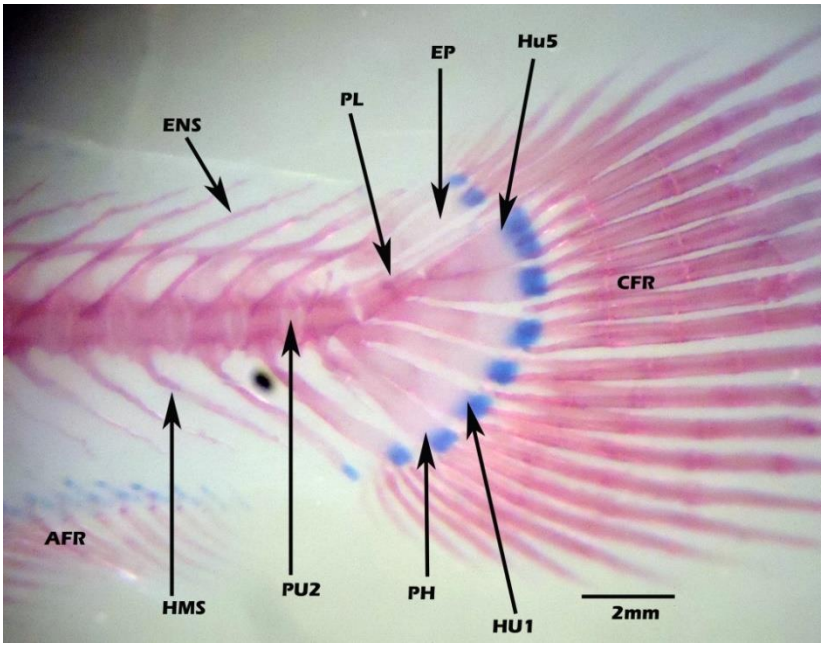

Plate 14. Alcian blue and alizarin red stained C. gariepinus*. Lateral view of caudal fin (20 dph). AFR, anal fin rays; CFR, caudal fin rays; ENS, enlarged neural spine; EP, epural; HMS, hemal spine; HU1, first hypurale; HU5, fifth hypurale; PH, parhypurale; PL, pleurostylar; PU2, second preural centrum; V, vertebra.*

3.6.3. Day 23 post–hatching *C. gariepinus*

The average lengths of 23 dph larva were 19.72±0.52 mm (n=7). At this stage all of the head bones were reduced in number and ossified (Plate 15a and b). The vertebrae were equipped with elongated fully ossified neural spine (ENS) on the upper and hemal spine (HMS) on the lower part (Plate 15c). The dorsal fin consists of 58 ossified rays. The pectoral fin possess 10 ossified fin rays, 6 pelvic fin rays and caudal fins have only 27 ossified fin rays (Plate 15d).

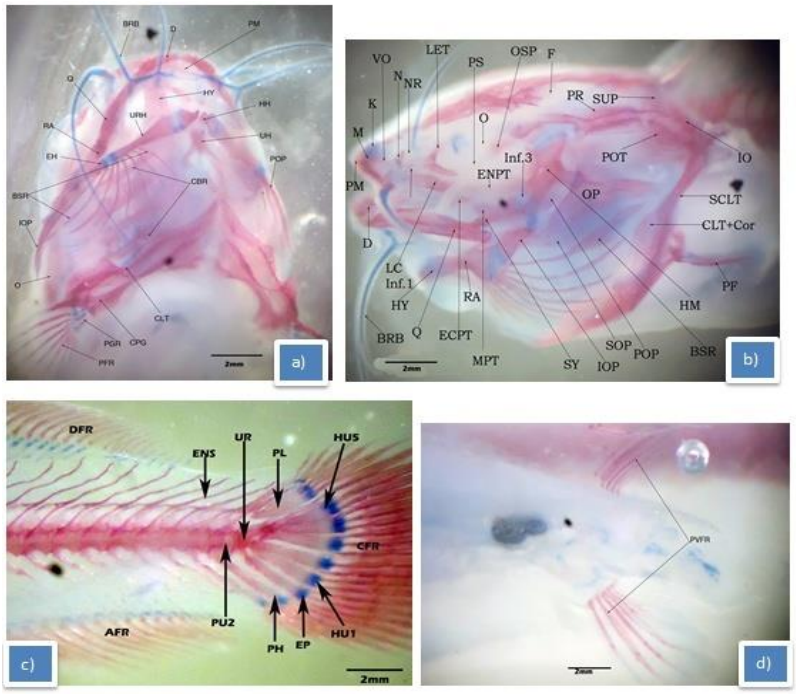

Plate 15. Alcian blue and alizarin red stained *C*. *gariepinus* (23 dph). a) Ventral view of neurocranium, b) Lateral view of chondrocranium, c) Lateral view of caudal fin, d) Ventral view of pelvic fin. AFR, anal fin rays; APT, autopalatine; BRB, barbell; BSR, branchiostegal ray; CBR, ceratobranchia; CFR, caudal fin rays; CLT, cleitrum; CPG, coracoid of pectoral girdle; D, dentale; DFR, dorsal fin rays; ENS, enlarged neural spine; EP, epural; F, frontale; HH, hypohyal; HMS, hemal spine; HU1, first hypurale; HU5, fifth hypurale, HY, hyoideum; INF II, Infra orbital II; IOP, interopercle; LCA, lacrymal antorbital; M, maxillas; MET, Mesethmoid; N, nasale; NS, neural spine; OP, opercle; PFR, pectoral fin rays; PGR, pectoral girdle; PH, parhypurale; PL, pleurostylar; PM, premaxilla; PS, parasphenoideum; POP, preopercle; PSOP, Purieto supraoccipitale; PU2, second preural centrum; PVFR, pelvic fin rays; Q, quadrate; RA, retroarticularis; SPH, sphenotic; UH, urohyal; ULS, upper lateral scute; URH, uratohyale.

3.6.4. Day 75 post–hatching *C. gariepinus*

A grown catfish at 75 dph with full structural development is shown (Plate 16). The average length of the 75 dph old larvae was about 116.0±3.1 mm and brownish in color.

Plate 16. Grown C. gariepinus *in natural growth condition (12 h light + 12 h dark) (75 dph).*

Discussion

Organogenesis

Many studies have revealed that most fishes require a minimal threshold light intensity to grow normally. However, light that is too intense might be stressful or even lethal (Han *et al*., 2005). In contrast with the above in our experiment *C*. *gariepinus* grew well in complete darkness. *Clarias gariepinus* larvae are photophobic. They live in covered habitats on the edges of lakes and rivers (Britz and Pienaar, 1992). Light avoidance behavior started shortly after hatching (current study). This is in agreement with Hecht and Appelbaum (1988) which demonstrated that in this species eyes were less important for prey capture, while the circum-oral barbels were essential. In contrast with many fish species, *C*. *gariepinus* is tactile and possibly chemoreceptive predator rather than visual predators. Hence, rearing in darkness was not expected to exert a negative effect on *C*. *gariepinus* survival, feeding and growth.

Survival and cannibalism

In the present study, fish in dark growth conditions showed the highest survival (92.8%) (Table 2). This finding was in agreement with result of Han *et al*. (2005) who worked on Chinese long snout catfish (*Leiocassis longirostris* Günther) and Mukai and Leong (2011) who reported that the survival rates of African catfish tended to be higher in dark than in light conditions.

Not only did light impair survival of juvenile *C*. *gariepinus* when applied during external feeding, but also the 'light history' was of significance. Suppressed survival was recorded in juveniles reared under the same conditions during external feeding, but incubated in light during yolk feeding: LL<DL and LD<DD (Table 2). A possible explanation may be that there were individuals in the L-group that, although they survived exposure to light during yolk feeding, were nevertheless slightly damaged by ultraviolet light during embryogenesis which could later be an easy target for cannibals.

Based on the observations made in this study, the larvae were more active under dark conditions than under illuminated conditions. Thus, the larvae are most likely nocturnal in habit. Under light conditions, the larvae showed resting behavior on the bottom of the aquarium during daytime; these larvae were then bitten by others larvae. Moreover, 7-day-old larvae displayed distinguishable resting behavior, in which they suddenly stopped moving and appeared to be unconscious under light conditions (Plate 1).This finding was supported by different studies. Mukai and Leong (2011) and Hecht and Appelbaum (1988) mentioned the resting behavior of *C*. *gariepinus* larvae; hence, under light conditions, the resting larvae will be more likely to be bitten by other individuals. Larvae and early juvenile African catfish are negatively photo-tactic and generally nocturnal and exhibit strong refuge seeking behavior under high light intensity. Experimental work has shown that early juveniles under satiation feeding condition reared under continual light display reduced browsing and swimming activity and exhibit increasing level of cannibalistic and territorial aggression (Clap *et al*., 1997). Consequently, survival rates probably decreased under light conditions. Accordingly, the survival rates under dark conditions were slightly higher than those under light conditions.

Different studies have demonstrated that *C*. *gariepinus* larvae, juveniles or fingerlings can be reared under continuously dark conditions and that survival rates under dark conditions are higher than under continuous light, or alternating light and dark conditions (Almazan-Rueda *et al*., 2008; Adewolu *et al*., 2008). The result of the present study is consistent with these results.

On one hand, Britz and Pienaar (1992) demonstrated that the activity of *C*. *gariepinus* larvae and juveniles under dark conditions is higher than under light conditions. On the other hand, many other studies mention that the activities of *C*. *gariepinus* larvae or juveniles are reduced under dark or dim light conditions; consequently, fish cannibalism decreases and survival rates increase. In our observations, larval activity became higher under dark conditions as the number of fish resting on the bottom of the aquaria decreased. Accordingly, we suggest that the higher activity of *C*. *gariepinus* under dark conditions resulted in reduced rates of cannibalism and higher rates of survival than under light conditions (Tables 1 and 2).

Ontogeny

The absences of information on ontogeny in general and on *C*. *gariepinus* in particular make comparison of results difficult with the present work. Success during ontogeny is mainly due to the rapid development of structures related to feeding and avoidance of predation. In *C*. *gariepinus* development of the mouth and anal apertures, eye pigmentation, the four barbel pairs and changes in the fin fold occur simultaneously with yolk absorption and are related to foraging ability, indicating the beginning of exogenous feeding (Kipper *et al*., 2013). In contrast with the above, our result showed that development of organs related to foraging and gas exchange which facilitate exogenous feeding were well developed and ossified before the absorption of yolk (Plate 2b).

The adaptation of most catfishes to a benthic and nocturnal lifestyle is reflected in several structural transformations. However, these are not restricted to the fully developed, bony skull, but arise early during ontogeny. When, for example, compared to the closely related Characiformes (according to the phylogeny proposed by Fink and Fink, 1981), the general trend in overall Clariidae head morphology seems to involve a reduction of eye size, as well as the dorso-ventral flattening of the skull. To a certain degree, this trend can be expressed as the ratio of the eye diameter to the interorbital distance (Adriaens and Verraes, 1997).

The bony development of the cephalic skeleton is quite variable in teleosts (Matsuura and Yoneda, 1987). At hatching, there is no ossified element in *C*. *gariepinus*, *H*. *longifilis*, *Barbus barbus*, or *Chrysichthys auratus* and *L*. *intermedius* (Vandewalle *et al*., 1995; Belay Abdissa, 2009). *Galeichthys felis* appears as an exception, since the dentaries, operculars, and premaxillaries are already present at hatching in this species (Vandewalle *et al*., 1995).

In this study, the first ossified structures were the maxillaries, dentaries, premaxillaries, operculars and cleitrum which appeared simultaneously at 2 dph (Plate 2b). This finding was faster by a day as compared to that reported by Vandewalle *et al*. (1997). The dentaries and maxillaries are particularly well developed in *C*. *gariepinus*, as in *Silurus* spp., *H*. *longifilis*, and *Chrysichthys auratus*, the maxillary is placed, at the outset, at the base of the barbel as in the

adult, and thus does not contribute to forming the contour of the mouth (Vandewalle *et al*., 1995).

In study done by Verraes (1977) on ontogeny of *C*. *gariepinus* and *Oncorhynchus mykiss* (Walbaum), the opercularsappear first, followed by the premaxillaries, the maxillaries, the dentaries, the inferior and superior pharyngeal tooth plates. The sequence of development and ossification was similar with our findings. Appearance of three pair of branchiostegal rays in our study was comparable with the result reported in *Chrysichthys auratus* when ossification of the skull begins with the dentaries, the opercularsand two pairs of branchiostegal rays, followed by the maxillaries and opercularsand (Vandewalle *et al*., 1995). Unlike the above studies, our experiment indicated that cleitrum, simplicticum and lacrimale appeared at 2 dph (Plate 2b).

In *Lophius gastrophysus* Ribeiro, there directly appears a pair each of maxillaries, premaxillaries, dentaries, opercularsand subopercularsand (Matsuura and Yoneda, 1987). In *Anisotremus davidsonii*, the first structures to appear were the premaxillaries, maxillaries, dentaries, preopercularsand opercularsand (Watson and Walker, 1992). However, unlike in this study, opercularsappeared before subopercularisand preopercularisat 2 dph (Plate 2b). The ossification sequence in our study was opercularsat 2 dph followed by subopercularis, preopercularisand interoperclum. Appearance of interoperclum in our study was different and was not even reported by Matsuura and Yoneda, (1987) and Watson and Walker (1992).

In many teleosts, after ossification of the pharyngeal jaws, the first four ceratobranchials are simultaneously added to the branchial basket, either just before or concomitantly with the epibranchials. In our study, the quadrates, epihyale, hyomandibulars, and palatines are the next to ossify before the ceratobranchials. The hypohyale were absent in our study up to 11 dph. However, results of our study were contradictory to studies of Vandewalle *et al*. (1995), work on *H*. *longifilis*, the quadrates, hyomandibulars, and palatines are the next to ossify after the ceratobranchials. The symplectics are absent in this species up to day 16, as in many adult Siluriforms. In agreement with our findings in many non-Siluriform teleosts, the hyomandibulars and palatines develop later, after the entopterygoids, and ectopterygoids. In *Lophius gastrophysus*, the palatines and quadrates are the first ones present, followed by the hyomandibulars (Matsuura and Yoneda, 1987). *Barbus barbus* and *L*. *intermedius* first displays ossification of the quadrate, then of the ento- and ectopterygoids, and finally of the hyomandibular and palatine (Vandewalle *et al*., 1997; Belay Abdissa, 2009). In *Esox lucius*, the hyomandibulars, symplectics, and quadrates all appear at the same time but quite a bit later than the ectopterygoids (Vandewalle *et al*., 1995).

In *H*. *longifilis*, the quadrato-mandibular joint appears at 5 days, the hyomandibulo-opercular joint at 6 days. These events occur in the same order in *Chrysichthys auratus* (Vandewalle *et al*., 1995). In *Barbus barbus*, the quadrato-mandibular and hyomandibulo-opercular joints become functional simultaneously (Vandewalle *et al*., 1997).

On the contrary in our study these events did occur a day before, where the joints of the Cleitrum with coracodium appeared to become functional quite quickly, as soon as sub operculum and simplicticum ossification begins. The quadrato-mandibular joint appears at 4 dph and the hyomandibulo-opercular joint at 5 dph (Plate 3a).

In our study after the appearance of the Mesethmoid (4 dph) anterior fontanel and frontals (5 dph), then formation construction of the bony neurocranium proceeded more slowly than that of the bony splanchnocranium. It wasn't until quite late that the braincase roof develops, with the appearance of the post-temporals, and supraoccipitals, accompanied first by formation of the sphenotics, then by construction of the front of the neurocranium, notably the frontals (8 dph). In different study some species such as *Anisotremus davidsonii* and *Xenistius californiensis*, the primordia of the frontals and of several other parts of the braincase appear quite early (Watson and Walker, 1992). In *Barbus barbus*, and *Chrysichthys auratus*, the supraoccipitals, pterotics, and sphenotics all develop concomitantly with the frontals (Vandewalle *et al*., 1995).

The later development of the rest of the bony skeleton involved the appearance of the front of the neurocranium, particularly the ethmoid region (lateral ethmoideum, parasphenoideum and petrosphenoideum), enlargement and the fusion of bones reduced the number of elements of the parts already present with all of the bone structure in the head region fully ossified (Plate 5b, 10b and 15b).

The developmental ontogeny of the caudal skeleton of *C*. *gariepinus* in our study was similar to that of *Clarias batrachus* (Fujita, 1992). Three cartilaginous hypurals from autogenously (3-5), whereas hypurals 1 and 2 were fused at their base at the moment of formation which later on also fused to the parahypural. The ossified caudal skeleton in catfishes occasionally showed a trend towards fused hypurals. In some catfishes, the pleurostylar skeleton comprises a generalized configuration (consisting of separated hypurals 3-5, a complex structure including the preural centrum 1, the parhypural, the first two hypurals, the corresponding preural centra and pleurostyle, and a separate epural). However, in several lineages, an increasing trend toward extensive fusion between hypurals can be observed, as for example in some anguilliform clariids, trichomycterids, and *Cavernicole ictalurids* (Lundberg, 1982). Caudal fin rays may be supported by two plates: a ventral plate formed by the parhypural and hypurals 1-2 and a dorsal plate formed by hypurals 3-5. Neural spines of the second and preceding preural vertebrae may also become elongated (Vandewalle *et al*., 1995).

The ontogeny of the vertebrae and fin rays (dorsal, pectoral, pelvic and anal) process was not as such complex. All the appearance of vertebrae started from the head region towards the caudal region. First appearance of the vertebrae evidenced at the base of the skull (Plate 2b and Plate 12a). Ossification began from peripheral part on both directions towards the center. Possessions of neural spine followed by hemal spines after fully calcified vertebrae appeared. These findings were in agreement with the results reported by Belay Abdissa (2009) on *L*. *intermedius*.

Dorsal fin rays appear first followed by pectoral, pelvic and then anal fin. Rahman *et al*. (2004) reported that dorsal fin was clear with 6–7 fin rays at 8 dph. This was in agreement with our result (dorsal, pectoral, pelvic and anal). Also ossification processes were similar with that of *L*. *intermedius* which started at the base towards its tip (Belay Abdissa, 2009).

The scarce pigmentation in the less developed larvae may be beneficial for the species. According to Kipper *et al*. (2013), larvae with little pigmentation are common in pelagic environments, and changes may occur when they explore other environments. These situations

witnessed in our study in all the three growth conditions fish take color of the existing environs. In the case of D-group, the fish exhibited dark coloration, L-group yellowish and N-group brownish (Plate 6, 11 and 16).The increase in pigmentation observed during development is indispensable for this camouflage and suggests behavioral changes in the fish.

According to Booth *et al*. (2004), the addition of shade covers significantly increased the skin lightness. This was contradictory with our findings where fish in dark and light growth conditions take their background color instead. Fish could adapt to the background color by changing the skin color (Fernandez and Bagnara, 1991; Fujimoto *et al*., 1991) and fish in brighter light normally resulted in concentration of the pigment and paling of the skin (Rotllant *et al*., 2003). This was similar to our results (Plates 11 and 16).

Plate 17. Grown C. gariepinus *with different body coloration (75 dph). a) Dark growth condition (DD), b) Light growth condition (LL), c) Natural growth condition (N) (12 h light + 12 h dark).*

Considering the two experimental and the control group on the ontogeny process, there were some difference in the appearance (Plate 17a-c), speed and ossification. For instance in dark group the sequence of development, number and ossification appearance was faster than the light and the control group by one day. For example, some of the organ development and appearance completed within an hour gap and though it was difficult to look the sequential ontogeny. Operculum, premaxilla, cleitrum and two pair of branchiostegal rays appeared at first in the dark group whereas in light group these structures appeared with one pair of branchiostegal ray after a day. In the case of control group, the organ appearance and development lag behind the light group and the process was too slow which helped us to follow the detail ontogeny.

Conclusions

In general, African catfish showed higher survival rates in the dark conditions than in the light conditions. The present study showed that reduced larval activity under light conditions made the larvae more vulnerable to cannibalism. When the larvae are reared in the hatcheries, their

survival rate is an important factor. It can be concluded from the present work that rearing *C*. *gariepinus* during the early life stage in the dark hastened both survival and growth positively.

Clarias gariepinus has a short embryonic development period and sense organs develop rapidly during embryonic stage. This makes a suitable aquaculture fish. Complete yolk sack absorption occurs at 4 dph and those reared catfish are expected to start feeding the larvae at this time. Developmental studies would enable us to understand the early embryonic developmental stages of *C*. *gariepinus* as a whole. The study provides essential information on the embryonic and larval development of *C*. *gariepinus* and such information could also be beneficial for comparative studies as a basis for further studies on the ontogeny of *C*. *gariepinus*.

Photoperiod mediated growth in *C*. *gariepinus* depending on light intensity which has been shown to differ greatly on growth and survival. Rearing *C*. *gariepinus* under dark condition showed higher tendency of survival rate than under light conditions. Commercial production of these fast growing catfish fingerlings in Ethiopia can be enhanced when hatchlings are raised in dark or dim conditions in continuously aerated hatchery system.

Recommendations

- The experiments need to be continued on the ontogeny of catfish in detail using standard procedures and equipment which were lacking in this study.
- Further studies are needed on the effect of photoperiod experiment to know about various biological functions.
- Further comparative studies of induced spawning using synthetic hormones should be carried out to minimize the time required for pituitary gland collections and processing.
- Larval rearing of African catfish under dark conditions is highly recommended, as it improves catfish survival rates and for better yield and profitability.

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