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Research Article

ALLOMETRIC GROWTH PATTERNS DURING LARVAL STAGES OF TWO MAJOR CARPS, CATLA (*CATLA CATLA*) AND ROHU (*LABEO ROHITA*)

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ABSTRACT

Morphological development and allometric growth of two hatchery-reared major carps catla (*Catla catla*) and rohu (*Labeo rohita*) were studied from hatching to metamorphosis (30 Days Post Hatch, DPH). The growth in terms of Total Length (TL) of *Catla* larvae from hatching until the juvenile stage increased from 5.9 mm TL to 43 mm. TL of Rohu larvae from hatching until the juvenile stage increased from 5.5 mm TL to 41mm. In both the species five developmental stages (yolk sac larvae, pre-flexion larvae, flexion larvae, post-flexion larvae and juvenile) were identified. The yolk sac stage lasted for about 3 days in *Catla* larvae while it lasted less than 3days in rohu larvae. In *Catla* larvae pre-flexion stage lasted from 4-9 DPH, flexion stage from 10 to 14 DPH and post-flexion stage lasted from 15 to 25 DPH. In rohu larvae pre-flexion stage lasted from 3-8 DPH, flexion stage from 9 to 13 DPH and post-flexion stage lasted from 14 to 23 DPH. Rapid and complex morphological changes were observed in both the species from hatching to post-flexion stages. The positive Allometry of head length from hatching to flexion stage of these fishes might be associated with the development of their sensory, feeding, respiratory and swimming systems.

Keywords: Major carps, Development, Allometry, *Catla*, Rohu.

INTRODUCTION

In the life cycle of fish, larval development is a complex process of growth and differentiation including morphogenesis and changes in body shape, metabolism and behavior. These allometric developmental changes are regulated by gene expression and influenced by the environment result in different phenotypes with differential relative growth (Enric Gisbert & Doroshov, 2006). In teleost fishes most functional systems are incomplete at hatching and larval period undergo a dramatic change in body form. Studies of Snik *et al.* (1997) in African catfish *Clarias gariepinus* and common carp *Cyprinus carpio* with special attention to fin fold revealed that many morphological characters showed fast allometric growth in early larval stage followed by isometric growth after an inflexion point. (Gisbert, 1999) divided the early development of the Siberian sturgeon *Acipenser baeri* into two different phases: the pre-larval stages between hatching and first feeding and larval stages between initiation of external feeding and metamorphosis. Morphogenesis and differentiation were intense during the pre-larval than larval and early juvenile stages. The pre-larval period was characterized by the replacement of embryonic adaptation and functions such as branchial respiration, exogenous feeding and active swimming. Positive allometry was seen for feeding, sensorial and respiratory function and the tail for reducing cost of transport, routine swimming and escape reactions from predators. This confirmed the hypothesis that growth patterns of early life closely matched the specific needs. Further, the profound transformations in the early life of fishes marked by substantial, sometimes dramatic changes in size, shape and structure govern a fish's physiological and behavioural capability (Fuiman & Higgs, 1997).

It is observed that there has been considerable variation in the ontogeny of different teleost species

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depending on their genetics and environmental factors encountered. Studies of Geerinckx *et al.* (2008) on early history stages of the loricariid catfish *Ancistrus triradiatus* with regard to metric characters revealed that the free-swimming embryonic stage is followed directly by the juvenile stage without a true larval stage or metamorphosis. Intense, but gradual ontogenic head- shape changes are present during the embryonic and free-living embryonic stages. The sucker mouth gradually shifts from an almost rostral to a ventral position. The external and internal transformations related to this shape change are considered an adaptation to its feeding and habitat.

The development and allometric growth pattern studies during early larval stages of the spotted sand bass *Paralabrax maculatofasciatus* by Renato Pena & Dumas, (2009) supported the hypothesis of differential growth patterns for primary functions during early ontogeny. In the case of sand bass *Paralabrax maculatofasciatus*, during the yolk sac and preflexion stages, there is an evident priority to enhancing the feeding and swimming capabilities by promoting accelerated growth in head and tail length. During the flexion stage, there is a major difference in the growth coefficient, indicating a change in growth priorities. At the end of post flexion stage, there is a tendency to isometry for all growth coefficients. The review of allometric growth during early larval development in different teleost groups by Osse & Van den Boogaart, (1995), suggests that Allometry is considered an adaptive response to counteract environmental pressures, increasing the probability of survival and growth during early development by producing changes in body form due to differential growth of organs and systems involved in the primary functions like feeding, respiration and locomotion, rather than organs which are a lower priority for survival. Hybrids between catla (*Catla catla*) and rohu (*Labeo rohita*) were found in the dams in and the morphological characters and growth rate of the hybrid were similar to those of *Catla* (Natarajan *et al*., 1976). These two species are widely mass cultured in South India. Considering the commercial importance of the two major carps, their Allometry during early development was investigated and reported in order to understand their feeding strategy and structural changes during larval development.

MATERIALS AND METHODS

For allometric studies catla (*Catla catla*) and rohu (*Labeo rohita*) larvae were randomly sampled (n=5) daily from hatch to 10DPH and at one day interval from 10-30DPH. The specimens were photographed by a video camera and measured image analysis software (AV Capture and Motic Software). Following morphometric characters were measured from hatched to juvenile: Total length (TC), head length, trunk length, tail length and eye diameter. The larval developmental stages identified and characters were measured following the system developed for larval carp. Allometric growth pattern were calculated as a power of TL with the exponent and intercept obtained from linear regressions on log-transformed data. The allometric equations $Y=ax^b$ of head length, trunk length, eye diameters and tail length on TL was estimated. Where Y is the independent variable, (TL) an intercept and b is the growth co-efficient. When isometric growth occurred b=1. Allometric growth is positive when b>1 and negative when b<1 (Snik *et al.*, 1997).

RESULTS

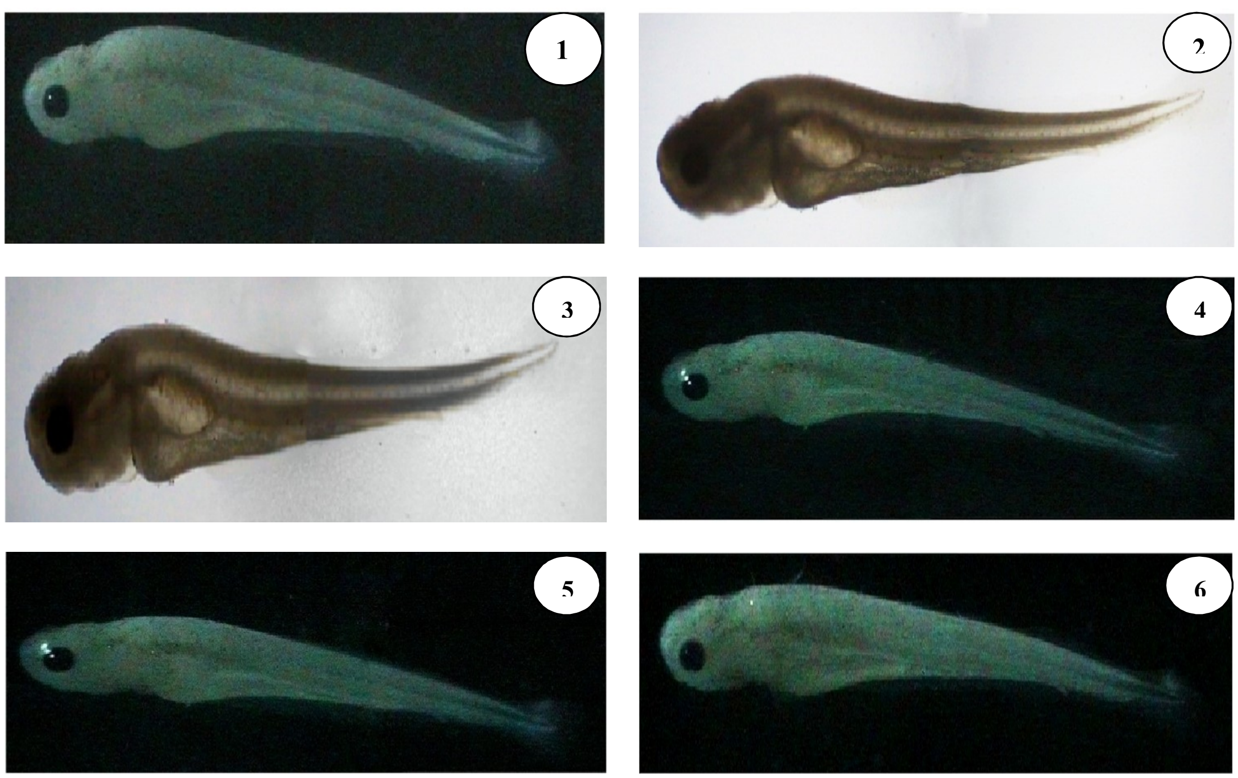
In the development of catla hatchling to juvenile, 5 stages were identified: yolk sac larvae, pre-flexion larvae, flexion larvae, post flexion larvae and juveniles (Table.1). The growth in terms of Total Length (TL) of Catla larvae from hatching until the juvenile stage followed an exponential curve. At hatching the larvae measured 5.9±0.4mm TL and reached 43±1.4 mm TL at the end of 30 DPH (Figure, 1-11). The yolk sac stage lasted for about 3 days with endogenous nutrition. It measured between 4.7 to 6.8mm. The second stage was the pre-flexion where the distal part of the notochord was straight and this stage lasted from 4 to 9 DPH. It measured between 7.2 to 14 mm. During this stage, endogenous as well as exogenous feeding was observed .The third stage was the flexion stage where the notochord underwent a distinct bending. The duration of this stage lasted from 10 to 14 DPH. During this stage, the total length of the larvae ranged between 15 to 25mm and it exhibited exclusively exogenous feeding. These three stages were characterized by drastic changes in larval form. The fourth stage larva was the post-flexion stage where the formation of skeletal structures commenced. The duration of this stage and the total length of the larva ranged between 26 to 36 mm. The last stage was the juvenile where the larva underwent metamorphosis and attained the shape and form of a small adult. This period was from 26 DPH onwards and the total length was about 43 mm.

The yolk sac larva of *Catla* during its endogenous nutrition period showed that the head and tail length was positively allometric in relation to total length (b = 1.2, r^2 = 0.91 & b = 1.12, r^2 = 0.89, respectively) whereas the trunk length showed negative allometric growth (b = 0.58, r^2 = 0.84). In the pre flexion stage, the head length showed positive allometric growth (b = 1.41, r^2 = 0.96), but the trunk and tail length showed negative allometric growth (b = 0.72, r^2 = 0.91 & b = 0.79, r^2 = 0.91, respectively). The flexion stage larva showed still positive allometric growth with regard to its head length (b = 1.1, r^2 = 0.95), while the trunk was negatively allometric (b = 0.79, r^2 = 0.91). The tail length growth in the larva of this stage was closer to isometry (b = 0.96, r^2 = 0.97). During the post flexion and juvenile stage, growth patterns of the head, tail and trunk length were almost isometric (b = 0.95, r^2 = 0.94, b = 0.93, r^2 = 0.97 & b = 0.98, r^2 = 0.97, respectively). With regard to the eye diameter, positive allometric growth was observed during the yolk sac, preflexion and flexion stage (b = 1.24, r^2 = 0.96, b = 1.18, r^2 = 0.95 & b = 1.11, r^2 = 0.91, respectively), while during post flexion and juvenile stage (b = 1.02, r^2 = 0.96 & b = 1.06, r^2 = 0.94, respectively) it had almost become isometric.

Table: 1. Main stages during *Catla catla* larval development.

Stage	Age (DPH)	Food source	Morphological observation
Yolk sac	1-3	Endogenous	Yolk sac present; undifferentiated digestive tract; mouth and anus closed.
Pre-flexion	4-9	Endo-exogenous	Mouth and anus open; differentiated digestive tract; notochord not flexed.
Flexion	10-14	Exogenous	Coiling of intestinal tract; gall-bladder and swim bladder anlage seen; notochord flexion commences.
Post-flexion	15-25	Exogenous	Further coiling of intestine; appearance of pronephros and mesonephros (kidney); notochord completely flexed.
Juvenile	26	Exogenous	Digestive tract fully differentiated; increase in size of liver and pancreas; development of gill filaments and lamellae.

DPH- Days Post Hatch.



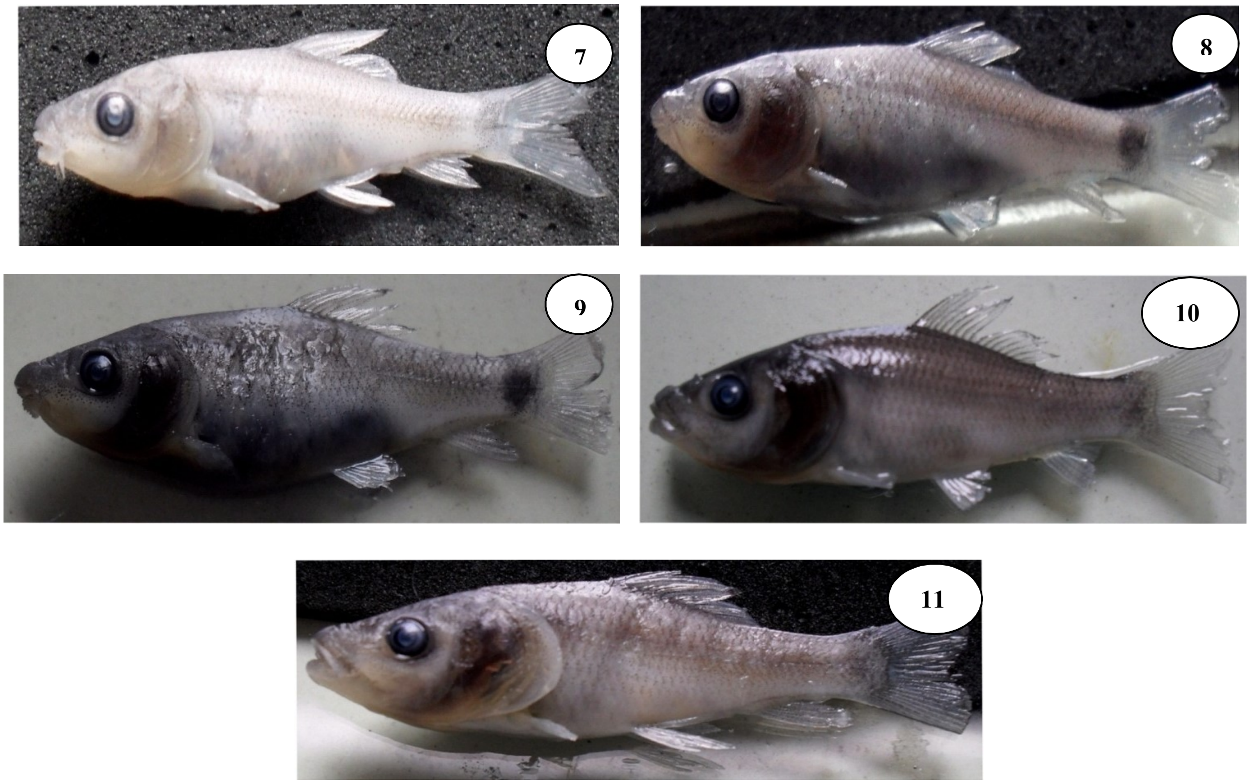


Figure 1-11. Different developmental stages of *Catla catla.*

Table 2. Main stages during *Labeo rohita* larval development.

Stage	Age (DPH)	Food source	Morphological observation
Yolk sac	1-3	Endogenous	Yolk sac present; undifferentiated digestive tract; mouth and anus closed
Pre-flexion	4-8	Endo-exogenous	Mouth and anus open; circulatory and respiratory systems commence functionality; differentiated digestive tract; notochord not flexed
Flexion	9-13	Exogenous	Coiling of intestinal tract; gall-bladder, swim bladder anlage seen; notochord flexion commences
Post-flexion	14-23	Exogenous	Further coiling of intestine; appearance of pronephros and mesonephros (kidney); notochord completely flexed
Juvenile	24	Exogenous	Digestive tract fully differentiated; development of gill filaments and lamellae

DPH- Days Post Hatch.

In the development of rohu larvae also five stages were identified: yolk sac larvae, pre flexion larvae, flexion, post flexion larvae and juveniles (Table 2). The growth of this species showed exponential pattern. The yolk sac larval stage lasted for less than three days with endogenous feeding and the total length ranged from 4-6.5mm. The preflexion stage lasted from 3-8DPH and the larva measured between 6.5-12mm, feeding showed an endo-exogenous as well as exogenous pattern. The flexion stage lasted from 9-13DPH and the total length ranged from 13-19 mm. The larvae exhibit exclusively exogenous feeding. The three stages are characterized by drastic changes in the larval form. The post flexion stage larvae last from 14-23 DPH and during this stage, ossification of the skeletal structure commences. The total length of larva ranged between 20-30mm. The final stage or the juvenile period involves the metamorphosis and attainment of small adult like form. This period is from 24DPH onwards and the total length at 30 DPH is 41mm. (Figure. 12-22)

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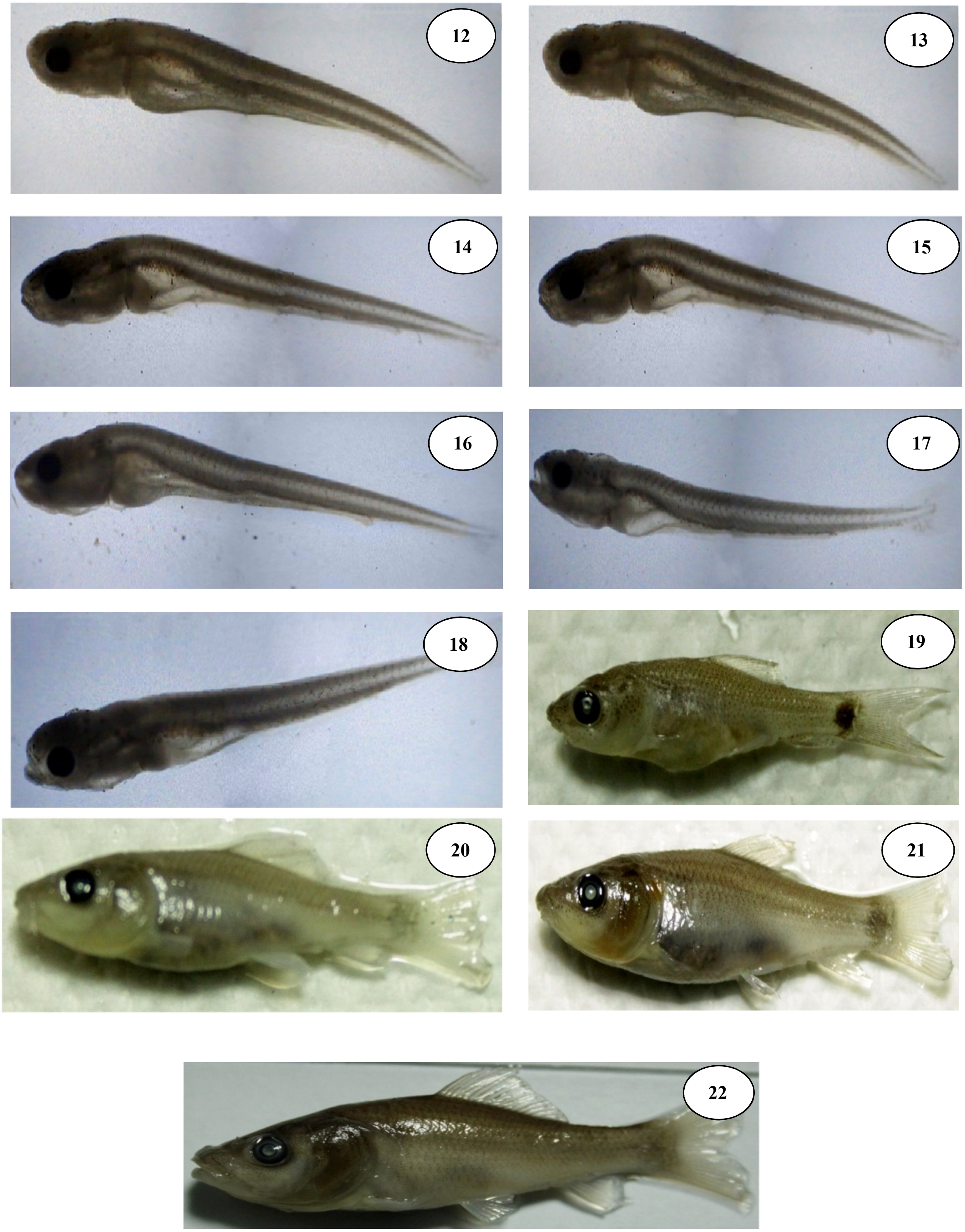

Figure 12-22. Different developmental stages of *Labeo rohita.*

Results regarding the growth patterns of rohu larvae yolk sac stage indicate that the head and tail exhibit positive allometry (b = 1.23, r^2 = 0.94 & b = 1.14, r^2 = 0.92, respectively) in relation to the total length. However the trunk length was negatively allometric (b = 0.62, r^2 = 0.91). In the preflexion stage the head length showed positively allometric growth, (b = 1.32, r^2 = 0.92) in contrast to the trunk and tail which exhibited negative allometric growth (b = 0.79, r^2 = 0.97 & b = 0.82, r^2 = 0.93, respectively). In the flexion stage larva positive allometric growth of head continued (b = 1.24, r^2 = 0.96), whereas the trunk was negatively allometric (b = 0.83, r^2 = 0.94), and the tail length of larva showed almost isometric growth pattern (b = 0.97, r^2 = 0.94). During post flexion and juvenile stage the growth patterns of the head, trunk and tail were almost isometric (b = 0.97, r^2 = 0.98, b = 0.95, r^2 = 0.98 & b = 1.01, r^2 = 0.97, respectively). With regard to the eye diameter positive allometric growth pattern was observed during the yolksac, preflexion and flexion stage of larval development (b = 1.21, r^2 = 0.96, b = 1.18, r^2 = 0.97 & b = 1.12, r^2 = 0.96, respectively), while during postflexion and juvenile stages it showed almost isometric growth pattern (b = 0.99, r^2 = 0.94 & b = 1.04, r^2 = 0.95, respectively).

DISCUSSION

The present allometric growth and ontogeny in Catla and Rohu larvae distinguished two episodes. First episode concerned with preflexion larva and was distinguished by reduced growth, but intense morphogenesis and differentiation processes. Organogenesis and allometric changes indicated that development priorities concerned feeding efficiency by improving detection ability (Sensory system development), ingestion capacity (head growth) and assimilation performance (digestive system differentiation), together with respiration efficiency (gill development). Second episode concerned with post flexion larvae and was distinguished by fast growth of trunk and tail, acquisition of adult axial muscle distribution and completion of gill filaments development, improving locomotion and oxygenation performances. It corresponded to transition towards metamorphosing stage as indicated by later isometric growth, musculature maturation and acquisition of juvenile phenotype. Determination of these relative growth patterns during early development could contribute to fisheries management and aquaculture by characterizing normal growth patterns under certain conditions and optimize rearing protocols if abnormalities in larval development are detected.

While discussing the developmental stages and morphological changes of larval stages of spotted sand bass (Renato Pena & Dumas, 2009) reported that results of their study were in accordance with the previously described by Butler & Moffitt, (1982) in reared larvae of the same species. However, the size distribution during each developmental stage and total length at juvenile transformation differed between two studies. Rearing conditions (feeding schedule and temperature) or genetic factor might explain stage differences. Nevertheless, in both studies the transformation to a demersal juvenile occurred in less than 30 days. In the present study also it is observed also it is observed that size distribution of each developmental stage and total length at the juvenile transformation differed in catla and rohu larvae which indicated that the variation in the growth parameters can be attributed to genetic factor more than environmental conditions. The changes in body form and consequently in functional development occur rapidly during early development. The growth coefficients obtained for catla and rohu showed differential growth of body proportions during each developmental stage, which support the hypothesis that in order to increase the probability of survival, a transition in ontogenetic priorities occurs during development (Osse *et al*., 1997; Osse *et al.*, 2004; Renato Peña & Dumas, 2009).

It has been observed in larvae of catla and rohu that from an incipient developmental state at hatching, differentiation processes takes place during the endogenous nutrition period to ensure a successful transition from endogenous to exogenous nutrition. The positive algometry of head and tail length during the endogenous nutrition period reflects the early priority to develop those structures and organs related to vital functioning such as feeding and swimming. The complete absorption of yolk material in the larvae of catla and rohu marks the beginning of preflexion stage. In this stage there was a change in the growth coefficients of head, trunk and tail segments. Increase in the growth coefficients of head segment might be due to the development of branchial structures. Positive allometry of trunk length might be due to the development of digestive tract. During this stage differentiation of various regions of the digestive tract is quit evident. Further the growth pattern of many morphometric features of catla and rohu larvae suggest that development of musculature, paired fins and caudal fin enhances the swimming ability of the larvae. During the flexion stage a shift in the growth allometry of catla and rohu larvae was observed. There is an evident reduction in growth coefficiencies of head, trunk and tail. Such a variations in the growth coefficiencies of morphometric characteristics have been reported in many teleosts (Kendall *et al.,* 1984; Snik *et al*., 1997;Kupren *et al.,* 2014; Pena *et al.*, 2003). The allometric study on catla and rohu larvae indicate the general pattern of ontogenic changes appeared to be related to the changing ecology of the species. The body proportions in the case of catla showed growth pattern for a pelagic mode of life and in rohu the feeding and swimming pattern more towards moving in the column of water (Rodríguez-Mendoza *et al.*, 2011). While studying the ontogenetic allometry of bluemouth *Helicolenus dactylopterus,* they also reported that the pattern of ontogenic changes seemed to be related to the changing ecology i.e. ontogenic diet and habitat adaptation. These changes consisted of relative expansion of the area between the second preopercular spine and pectoral fin, a relative deepening and shortening of the body and an upward shift of the snout as the head becomes more compact in relation to the body. However, the degree to which the ontogenic body shape and size changes observed in the *Catla*, rohu and other fishes from each of the study areas might be different, indicating that growth trajectories are not homogenous. The factors that cause these growth differences are likely to be complex, but a combination of factors such as food availability along with a low fishing mortality and unique environmental conditions likely to produce distinctive growth patterns.

CONCLUSION

For fishery management the studies will be useful to compare the natural populations with the hatchery produced and also to understand and optimize the larval stocking densities and feeding strategies.

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