POECILIID RESEARCH

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Research Article

Allometric growth pattern of the swordtail - *Xiphophorus helleri* (Cyprinodontiformes, Poeciliidae) during early development

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Abstract. This study was conducted to survey the allometric growth pattern of the swordtail (*Xiphophorus helleri*) during early developmental stage under rearing conditions. For this purpose, the fries were sampled after birth up to 60 day after birth (DAB), their left sides were photographed and morphometric parameters, including total length, head length, tail length, trunk length, eye diameter, snout length, and body depth were measured. The newly hatched fries were 8.3 ± 0.431 and 12.58 ± 0.234 mm in TL on 1 and 60 DAB, respectively. The results revealed growth priorities of this species during the early developmental stages. Based on the results, this species born with developed jaws and eyes that capable them to take the food immediately after birth and increasing the size of the mouth afterward to take larger food item. The inflection points of the most body segments are occurred during 30-35 days after birth showing a late morphological change in compare to oviparous species. These morphological changes are associated to head and snout lengths may be related to changing in feeding habit of this species. In addition, positive growth pattern of tail length is occurred earlier on 7 DAB improving its swimming capability to avoid predators and catch preys.

Key Words: livebearer, morphometric, aquarium, growth pattern, ontogeny.

Introduction. Early development in fishes is important because most functional structures have not been developed in larvae, and they undergo a complex morphogenesis and can follow markedly different growth trajectories (Gisbert et al 1998; Mousavi-Sabet et al 2014a), with organs developing in a stepwise manner in terms of changes in morpho-anatomical characters (Russo et al 2007) which improves behavioral and physiological capabilities (Peña & Dumas 2009).

Differential relative growth pattern of various body parts is defined as allometry (Fuiman 1983; Dettlaff et al 1993) that is a common feature during early larval development, ensuring to develop functional organs with their priority for survival and ontogenetic shifts in priorities (Osse & Van den Boogart 1995; Osse et al 1997). Studying the allometric growth patterns in early developmental stages of different teleost species can help to corroborate the importance of morphological development and growth patterns of young fish, by providing a better understanding of early life events (Khemis et al 2013) and their priorities during this period (Gisbert 1999).

The swordtail (*Xiphophorus helleri*) is a popular ornamental fish species of the family Poeciliidae, and its name derived from the elongated lower lobe of the male's caudal fin (Jacobs 1969; Dawes 1991). This species inhabits in fresh and brackish waters and is native to North and Central America stretching from Veracruz, Mexico, to northwestern Honduras (Nelson 2006) and is characterized by viviparity and internal fertilization as other poeciliids. Sexual dimorphism in this species is moderate, with the female being larger than the male, but lacking the elongated lower lobe of the caudal fin. Sexual maturity in *X. helleri* is reported at 25-30 mm in TL or at 10-12 weeks of age (Dawes 1991). Mature male is distinguished by the modified anal fin called gonopodium (Dawes 1991). In addition, *X. helleri* has become an exotic pest as an introduced species in some countries such as Iran (Esmaeili et al 2010) and has caused ecological damage because of its ability to reproduce rapidly (Esmaeili et al 2010; Mousavi-Sabet et al 2014b).

Since, the data about its early morphological development and allometric growth pattern is crucial to promote the development of optimal rearing protocols and improves the production efficiency of high-quality juveniles (Russo et al 2007). Therefore, the allometric growth pattern and morphological development of *X. helleri* were studied in a controlled aquarium condition before appearance of sexual dimorphism.

Material and Method. A total of 60 one-month old juveniles of *X. helleri* were obtained from a local ornamental fish farm in September 2013 and transferred to two 100 L rearing fiberglass tanks at the fisheries laboratory of University of Tehran (Karaj, Iran). During rearing period, they were fed with mixture of the *Artemia* nauplii and commercial food pellet (Biomar, Denmark; 58% protein, 15% lipid) at 5% of their body weight twice a day. Throughout this period, water temperature, dissolved oxygen and pH were 24-26°C, 7.5±0.6 and 7.2±0.1, respectively.

After nearly 3 months, a total of twenty ripe females were randomly sampled and transferred to the 100 L breeding aquarium. After giving birth, the newly born fish were collected and transferred to the 60 L glass aquarium with continuous aeration. During the rearing period of fries, water temperature, dissolved oxygen and pH were similar to those above mentioned conditions and fries were fed using *Artemia* nauplii and micro-worms (*Panagrellus redivivus*) and along with their growth with a mixture of the *Artemia* nauplii and above mentioned Biomar commercial food pellet.

A total of 70 specimens from 1 to 60 day after birth (DAB), were sampled as following: 1, 3, 7 and 10 DAB, followed every five days untill 60 DAB by a scoop net (n = 5), anaesthetized using 1% clove oil and their left sides were photographed by a stereomicroscope equipped with a digital Cannon camera with a 5 MP resolution. The sampled fries were preserved in 5% phosphate buffered formalin and stored in 70% ethanol after 24 hours for further examination. The visceral contents of the specimens were examined under stereomicroscope to determine their sex that was not detectable up to 60 DAB; therefore, the measured morphometric data of two sexes were pooled and analyzed.

Seven morphometric characters, including total length (TL), head length (HL), tail length (TaL), trunk length (TrL), eye diameter (ED), snout length (SnL) and body depth (BD) were measured. All measurements were taken along lines parallel or perpendicular to the horizontal axis of the body from obtained images using ImageJ software (version 1.240) (Figure 1).

The allometric growth patterns were calculated as a power function of total length using non-transformed data: $Y= aX^b$, where Y is the independent variable; X, the dependent variable; a, the intercept and b, the growth coefficient. Isometric, positive and negative allometric growth patterns are indicated by b = 1, b > 1, b < 1, respectively (Van Snik et al 1997). A t-test was performed to compare growth coefficients to determine whether b values differ significantly from the isometric value (Choo & Liew 2006). Robustness of the regression was measured by calculating R2 and its significance level.

The inflexion points of growth curves were determined based on Fuiman (1983) and Van Snik et al (1997). Drawing plates and data analysis were performed in MS-Excel 2013 (Microsoft Corporation). Data analysis was performed Past 2.17 for Windows.

For study of the morphological changes during early development, the specimens were examined for observations on general morphology, pigmentation and fin development by a stereomicroscope (Leica M5).

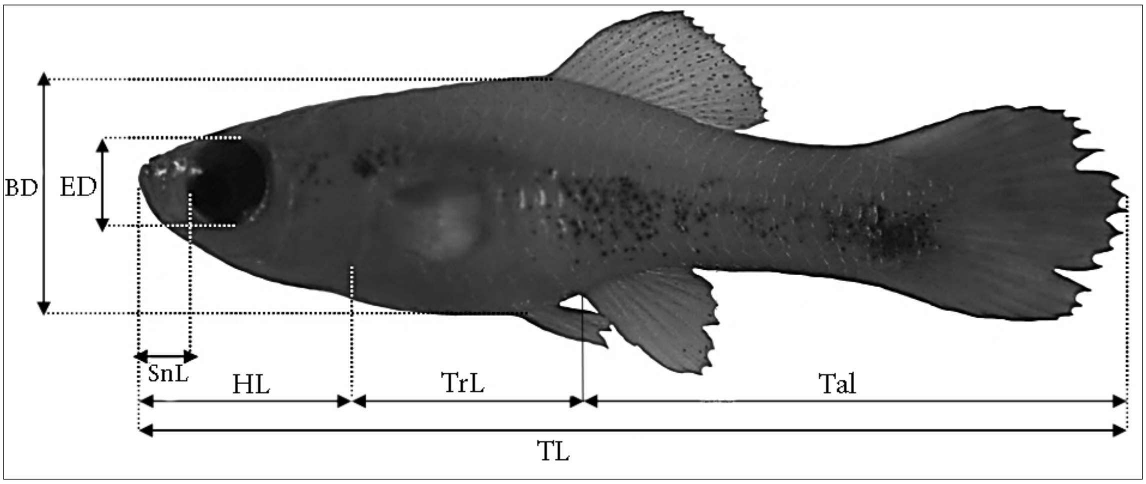

Figure 1. Measured morphometric characters in *Xiphophorus helleri* from 1 till 60 day after birth.

Results and Discussion. Study of allometric growth pattern is a common method during early development of fishes, since it contains important information on ecological and biological demands and functional performance of fishes (Gisbert et al 1998; Osse & Van den Boogaart 1995; Huysentruyt et al 2009; Peña & Dumas 2009; Çoban et al 2012). Based on the results, *X. helleri* as a livebearers species showed that many of its biological system are functional at the moment of birth. These features may be related to its ecological and biological demands in compare to those of oviparous species (Peña & Dumas 2009).

The newly born fries were 8.3±0.431 and 12.58±0.234 mm in TL on 1 and 60 DAB, respectively. The results showed that growth pattern of all body segments can be divided into two phases (Figure 2). Allometric growth of the HL (b = 1.1347) and SnL (b = 1.604) showed a positive pattern prior to their inflection points, at 10.77 and 10.49 mm in TL, respectively (on 35 and 30 DAB, respectively), and after inflection points, their allometric growth patterns were isometric and positive for HL (b = 1.0519) and SnL (b = 1.2914), respectively. In addition, the growth pattern of ED was negative during early developmental stage up to 60 DAB.

A positive allometric growth pattern of the snout length during early development of *X. helleri* may be related to changing its feeding habit, e.g. to obtain larger food items, implying importance of feed selectivity during early developmental stage (Yúfera & Darias 2007). The size of mouth has an important effect on prey catching (Hjelm et al 2003). As fish larvae grow, the size of their food typically changes as larvae prefer larger prey with higher nutrient and energy values (Sabatés & Saiz 2000; Østergaard et al 2005). Additionally, there is a correlation between ingested biomass and the larvae's effort cost to capture the prey (Cunha & Planas 1999). Hence, feeding shifts and morphological changes in *X. helleri* is concomitant. In fact, fries can take the food by developed jaws on the mouth, similar to the guppy (Mousavi-Sabet et al 2014a).

As fries of *X. helleri* born, the allometric growth patterns of the head and snout lengths were positive. The head are associated with the nervous and sensory systems for prey detection (Fuiman 1983; Koumoundouros et al 1999; Arnold 1974). Osse (1990) also reported a relationship between head volume and its suction forces, which is in agreement with changes in head and buccal cavity. The development of the gills could be another reason for the positive allometry of the head. Therefore, the growth pattern of the head in *X. helleri* i.e. developed at the born and positive allometry at the first phase, showing importance of the head growth to survive during this period. The negative growth pattern of the eye can interpret that this sense is developed at the hatching to function completely enabling fish to follow points of reference moving across their field of vision (Arnold 1974). Hence, its growth is less in compare to other body segments during later developmental stage.

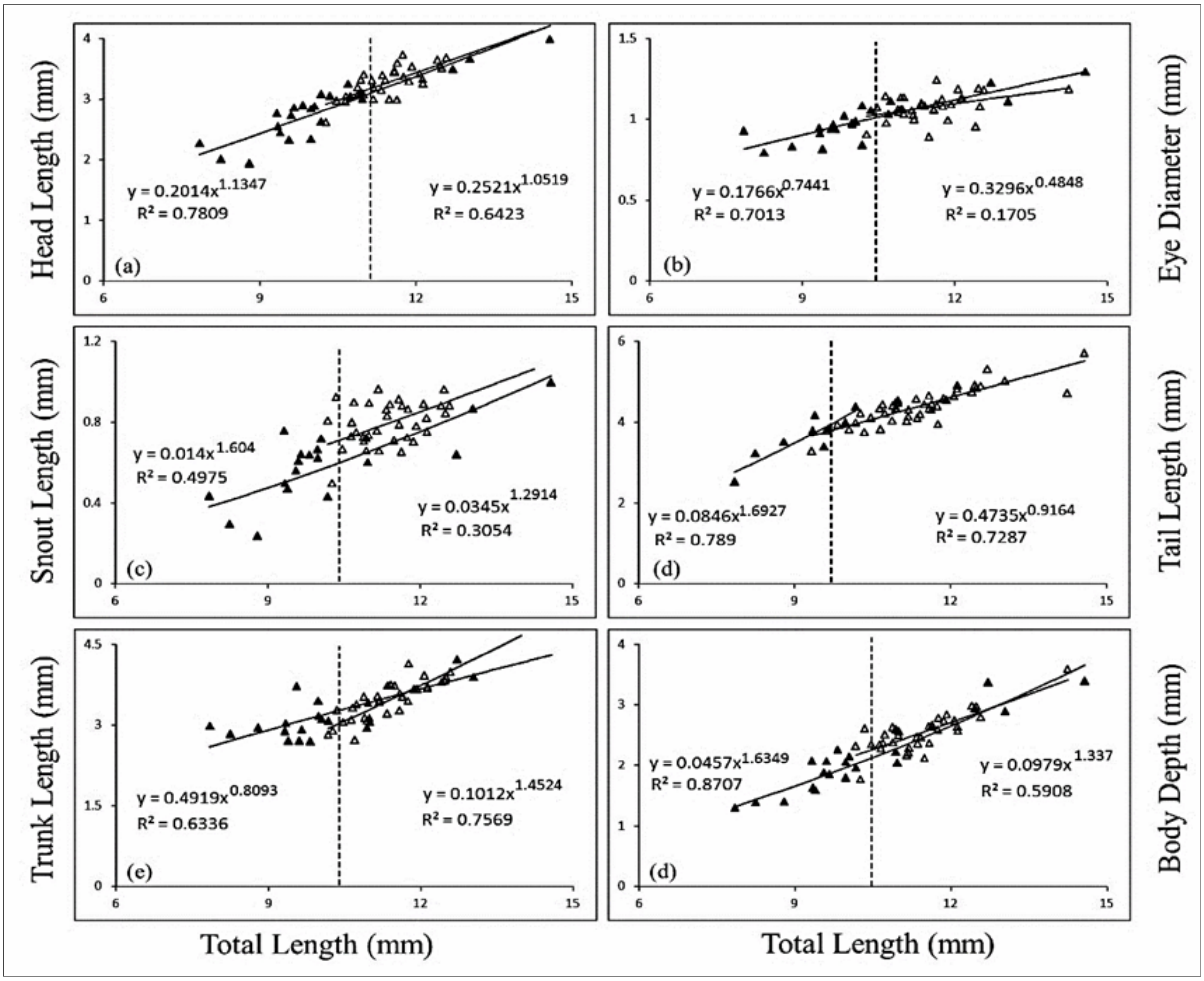

Figure 2. Growth allometries of the different body segments of *Xiphophorus helleri* (R2 = correlated coefficient).

The allometric growth patterns of TrL (b = 0.809) was negative, whereas that of BD (b = 1.634) was positive prior to their inflection points, at 10.49 mm of TL (on 27 DAB). During post inflection point, allometric growth patterns of TrL (b = 1.4524) and BD (b = 1.337) were positive. The positive allometric growth patterns of the trunk length and body depth during early development especially after 30 DAB can be related to development of the abdominal visceral organs such as alimentary tract (Mousavi-Sabet et al 2014a) that can be related on priority of this body parts during this period. In addition, the positive growth pattern of body depth can be as result of the musculature development and skeletal formation associated with food uptake and increasing body mass. Fast growth of the depth and length of trunk also improves the flexibility of body reflecting on prey choice and fish capability to use a wide range of food items from surface to bottom of water column (Andrade et al 1996). The swordtail prefers swift-flowing, heavily-vegetated rivers and streams, but is also found in warm springs and canals (Miller et al 2005). A positive allometric growth pattern of the body depth reflects obtaining a deeper body shape. Such a body form is related to rapid turning and maneuvering (Ontario 2015) particularly in heavily-vegetated rivers and streams.

The growth pattern of TaL was positive (b = 1.692) before its inflection point and after this point in 9.8 mm of TL (7 DAB), its pattern changed to almost isometric (b = 0.9164). The positive allometry of tail is related to locomotory and swimming capability enabling fries to avoid from predator and may help to swim faster and catch preys (Fuiman 1983) showing its priority before its inflection point on 7 DAB.

Conclusions. The results of this study revealed that *X. helleri* born with developed jaws, fins and eye that capable them to take the food, swim properly and avoiding predators immediately after birth. The allometric growth pattern of this species showed that the inflection points of the most of body segments occur during 30-35 days after birth showing a late morphological change in compare to oviparous species. These morphological changes are associated to head and snout lengths may be related to change in feeding habit of this species. In addition, positive growth pattern of tail length is occurred earlier on 7 DAB improving its swimming capability to avoid predators and catch preys. This study showed that important morphological modifications during early life stages of *X. helleri* holding valuable information on changes in functional demands throughout ontogeny with its adaptation to adult life style.

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