Allometric growth patterns in larvae and juveniles of Nile tilapia, *Oreochromis niloticus* (L., 1758)

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Abstract. This study was carried out to examine morphological changes and allometric growth patterns in Nile tilapia (*Oreochromis niloticus* (L., 1758)), as a valuable aquaculture species, during early developmental stages (from hatching up to 40 days after hatching) under rearing conditions. For extracting morphological data, a total of 160 larval specimens were collected in different days, then the left side of the specimens was photographed, and eight morphometric characters including body height, caudal peduncle height, eye diameter, head length, postorbital length, standard length, snout length and total length were measured. The larvae are born with developed feeding system and vision (jaws and eyes) that able them to see and take the food items immediately after hatching. These morphological changes in head (snout and eye) and caudal regions may be related to changes in feeding and swimming (to avoid predators) habits of this species.
Key Words: ontogeny, allometry, inflection, growth pattern.

Introduction. The goals of dynamic morphology are to define the quantitative and qualitative changes in growing animals as adaptations to changing demands of environment and function (Osse 1989). During the larval stage, important quantitative and qualitative morphometric changes take place, that are responsible for a progressive transformation of new hatched larvae from a larval body shape to a juvenile or adult form in a relatively short time. This suggests that growth functionally optimized for survival is a common feature among fish larvae (Osse & van den Boogart 2004).

The information on larval morphology and relative growth patterns during life history is fundamental to understanding many aspects of fish biology and improvement of cultivation techniques can result from a better understanding of growth (Martínez-Lagos & Gracia-López 2009; Çoban et al 2009). Allometry is defined as the relative growth pattern of different parts of the body (Fuiman 1983; Dettlaff et al 1993) that it is a typical feature during the initial period of larval development and due to the diversity in growth priority, the ontogenetic changes and survival, ensures the development of vital organs and their functions (Osse & Van den Boogart 1995; Osse et al 1997). Fish larvae experience complex processes of morphogenesis and differentiation during early life history by altering their body shape, metabolism rate, swimming ability and behavior (Koumoudouros et al 1999; Eagderi et al 2017).

Nile tilapia, *Oreochromis niloticus* is one of the most important and useful species of cichlids, not only for freshwater aquaculture (FAO 2004), but also for research in physiology (Wright & Land 1998), endocrinology (Melamed et al 1998; Seale et al 2002), genomic biology and molecular genetics (Lee et al 2005; Santini & Bernardi 2005), osteology (Fujimura & Okada 2008), and ontogeny (Fujimura & Okada 2007).

Since, this species is important for aquaculture, developmental information may offer criteria for the proper synchronization of zootechnic decisions (use of automatic feeders, etc.) with the stages of development of fish during early ontogeny. In this study, individuals of Nile tilapia larval, cultured in experimental conditions, have been studied to describe the development and allometric growth patterns in their early stages of life.

Material and Method. For this study, the freely swimming larva were transferred in 65 liter freshwater aquaria that water was 28ºC temperature and maintained in them until the end of the experiment. The experiment was repeated with three different batches of eggs. After yolk-sac absorption, free-swimming larvae were fed with commercial tropical fish food. During the rearing period, larvae were fed first by Artemia nauplii (*Artemia franciscana*), then a mixture of the Artemia nauplii and Biomar commercial food pellet was added to their diet.

For the allometric growth patterns, a total number of 160 specimens from 1 to 40 DPH (Day Post Hatch), were sampled as following; 1, 2, 3, 4, 5, 7, 9, 11, 15, 18, 21, 24, 28, 32, 36 and 40 DPH. Ten specimens were randomly sampled for different stages by a plastic pipette and scoop net, and anaesthetized using 1% extracted clove oil and then the left side of fish was photographed using a digital Cannon camera with 12-megapixel resolution. Because their sex was not detectable up to 40 DPH, therefore the measured morphometric data of two sexes were pooled and analyzed. Seven morphometric characters (Table 1) were measured along lines parallel or perpendicular to the horizontal axis of the body from obtained images using Image J software (version 1.240) (Figure 1).

In order to achieve allometric growth patterns, non-transformed data is used, which this patterns is represented by power functions of the total length values: $Y = aX^b$, where Y is the independent variable; X, the dependent variable; a, the intercept and b, the growth coefficient. We considered growth as isometric when b = 1, allometric positive when b > 1, and allometric negative when b < 1 (Van Snik et al 1997). Robustness of the regression was measured by calculating r^2 and its significance level. Fuiman (1983) and Van Snik et al (1997) was used to calculate the inflexion points of growth curves. Excel software was used to analyze data and draw charts (Microsoft Corporation).

Table 1

Abbreviations of seven morphometric characters measured in Nile tilapia

No.	*Abbreviation*	*Character*
1	B.H	Body height
2	C.H	Caudal peduncle height
3	E.D	Eye diameter
4	H.L	Head length
5	Pe.L	Post eye length
6	S.L	Standard length
7	Sn.L	Snout length
8	T.L	Total length

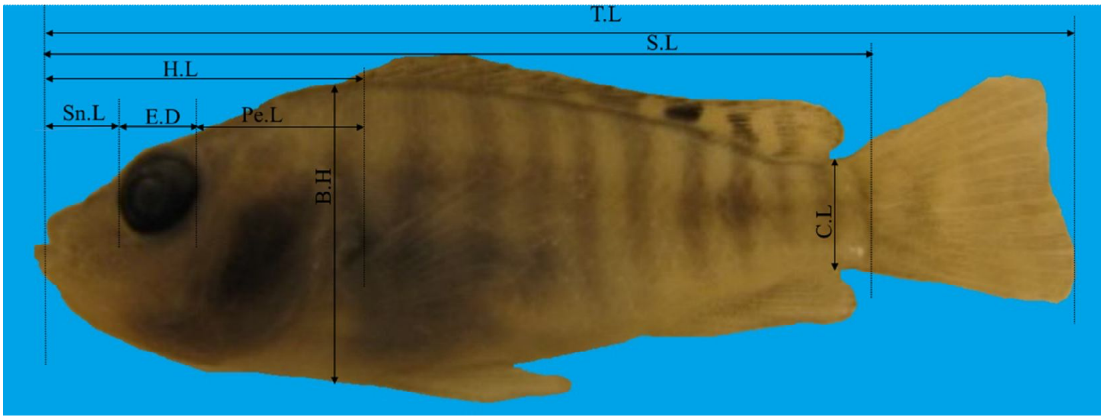

Figure 1. Measured morphometric characters on an *O. niloticus* specimen.

Results. Observations of new-hatched fries showed that T.L was 5.69±0.25 and 34.66±5.40 mm (mean±SD) in 1 and 40 dph, S.L was 5.01±0.27 and 27.04±4.23 mm in 1 and 40 dph, H.L was 1.06±0.12 and 10.17±1.40 mm in 1 and 40 dph, Sn.L was 0.21±0.07 and 2.93±0.63 mm in 1 and 40 dph, Pe.L was 0.46±0.11 and 4.97±0.71 mm in 1 and 40 dph, E.D was 0.50±0.08 and 3.02±0.36 mm in 1 and 40 dph, B.H was 0.49±0.09 and 10.27±1.66 mm (mean±SD) in 1 and 40 dph, C.H was 0.32±0.13 and 3.85±0.73 mm in 1 and 40 dph, respectively. So, S.L was 88% of T.L in day 1 reaching 78% in day 40, H.L was 19% of T.L reaching 29%, Sn.L was 4% of T.L reaching 8%, Pe.L was 8.11% of T.L reaching 14 %, B.H was 9% of T.L reaching 30%, C.H was 6% of T.L reaching 11% in days 1 and 40, respectively (Figure 2).

The body proportions changed considerably during the larval period and early life history of *O. niloticus*. The growth coefficients (b) in case of H.L, Sn.L, Pe.L, E.D, B.H and C.H was a clear reduction after the inflection points from positive or near-isometric (b = 2.03, 1.83, 1.17, 0.99, 1.44 and 1.33, respectively) to near-isometric or negative (b = 0.97, 1.18, 0.997, 0.61, 1.03 and 1.04, respectively) growth. Although the growth coefficients (b) in case of S.L was a clear increase after the inflection points from negative growth (b = 0.89) to near-isometric (0.99).

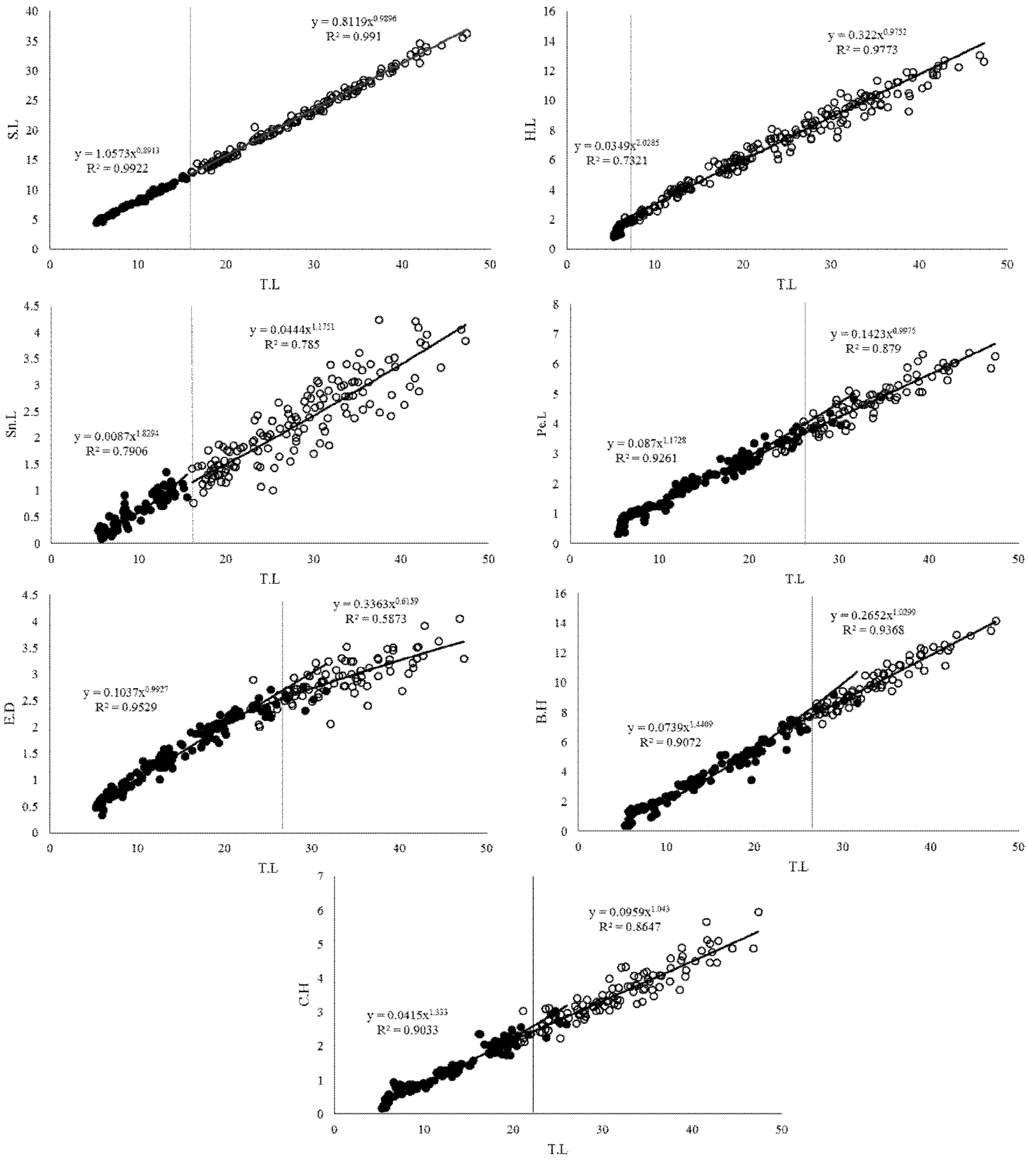

Figure 2. Allometries growth of the different body segments in *O. niloticus* (R^2 = correlated coefficient).

Discussion. Our data showed that body shape in Nile tilapia changes during the early development process and as a result, the Nile tilapia become longer proportionally faster than the increase in other lengths. We quantified that differences by comparing the observed changes in body proportions with those expected among the fish if growth was isometric, retaining the hatching proportions.

The early developmental study of *O. niloticus* as a mouth breading species showed that many of its biological systems are functional at the moment of birth. A positive allometric growth pattern of the cephalic region of *O. niloticus* including head length, snout length, pre-eye length and eye diameter during early development (before inflection points) and reduction these to near the isometric after inflection points may be related to different reasons such a fast allometric growth of the cephalic region; among priorities, there is an enhancement of vision and most likely all sensorial systems. This was notably supported by the positive allometric growth of eye diameter during early life history (Khemis et al 2013).

For the rapid initial (positive allometric) head region growth in fish larvae, van Snik et al (1997) and Gisbert (1999) suggested that the development of the encephalon and other sensory (vision and olfaction), respiratory (gill arches and filaments) and feeding organs is a priority in this phase of life, facing the need to interact with the environment, like many other fish (Nogueira et al 2014; Osse & van den Boogaart 2004). Higher suction forces can be related to head volume (Osse 1990), which implies that a fast head growth (as is the case here) would indeed allow an increase in suction efficiency.

A near isometric growth pattern of the standard length during early development (before inflection points) and its reduction to negative allometric after inflection points and a positive allometric growth pattern of the body height and caudal peduncle height during early development (before inflection points) and their reduction to near isometric after inflection points of *O. niloticus* was seen. Growth in caudal peduncle height and length may be related to the modifications of the swimming performance of fish in early life stages (Nogueira et al 2014; Fuiman 1983) and predator avoidance (Fuiman 1983; Huysentruyt et al 2009).

These different patterns are clearly detected by allometric deviations that are related to developmental or/and behavioral changes during the laryngeal ontogeny. It is admitted that differences in relative dimensions of body parts and organs between new-hatched fish larvae and post-metamorphic juvenile stages are due to the necessity of setting priorities during early larval growth to create at least primary conditions for survival (Osse & van den Boogart 1995; Osse 1989).

The ontogenetic development levels are species-specific during the hatching time of embryos and it depends on some larval traits, such as reproductive method and larval lifestyles and also largely depends on certain environmental conditions, especially water temperature (Korzelecka-Orkisz et al 2009; Teletchea et al 2008). During a short period, growth slows down. Like the results of this study, all growth coefficients, in older larvae and juveniles, are close to one (Gisbert 1999; Osse & van den Boogart 2004). These changes to isometry, observed particularly in anterior and posterior body regions, is considered to be a natural transition in growth priorities since the primary functions, such as feeding and swimming, were fulfilled during early development (U-shaped pattern of development) (Fuiman 1983).

Conclusions. Rapid head and postanal segment growth are necessary for the survival of early-stage individuals of fish, especially in Nile tilapia. In addition, changes in allometric growth observed in the body proportions of early life history likely result from selective organogenesis directed towards survival priorities during the initial life as indicated by different authors.

Acknowledgements. The authors would like to express their sincere gratitude to Dr. E. Ebrahimi for providing the fish. This study was financially supported by Isfahan University of Technology. There is no conflict of interest for this paper.

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Received: 05 March 2020. Accepted: 22 March 2020. Published online: 30 March 2020.

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How to cite this article:
Zamani-Faradonbe M., Keivany Y., Kermani F., 2020 Allometric growth patterns in larvae and juveniles of Nile tilapia, *Oreochromis niloticus* (L., 1758). Ecoterra 17(1):7-12.