Development and Allometry Patterns of Fine Scale Fish Larvae at Low Temperature

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Abstract. Ecological experiment was conducted to study the allometry of fine scale fish yolk-sac larvae and its significance in adaptation in early life stage. The results indicated organs such as feeding, breathing and swimming of larvae in the yolk sac stage are rapidly differentiated, and all key organs are allomorphic. In all parts of the body, the head length and tail fin length are growing at an allometric speed, the trunk is growing at a slow speed, and the body height is isokinetic growth; in the head organs, the rostrum length and head length are growing at a positive allometric speed; in the swimming organs, tail fin length is positive allometric growth; yolk sac width and yolk sac height are positive allometry consumption. The fast development of feeding, breathing, swimming and other organs in yolk-sac larvae of fine scale fish, increases larval survival ability at the early stage in the shortest possible time, and there were important ecological significance to adapt the complex and changing external environment.

1. Introduction

Allometry means that the relative growth rate of a certain feature of an organism that is not equal to the relative growth rate of the second feature. The functional organs of the body show a phenomenon of asynchronous growth, It is a developmental feature that animals and plants have evolved and adapted to the external environment for a long time [1, 2]. During the early development of fish, the development of various organs in many larvae also has different growth stages. That is, the organ has a faster growth rate than the whole in early development, until the organ is completely developed, or after the development reaches a certain stage, the growth is significantly slower or it is shown as constant growth compared with the whole [3,4]. Therefore, by studying the early growth model of larvae, it is of great ecological significance to understand the priority of organ development, grasp the important role played by various organs at different developmental stages, and explain the reasons for their behaviors such as evading enemies and actively feeding in the living environment.

The fine scale fish (Brachymystax lenok, Brachymystax, Salmonidae) is mainly distributed in Heilongjiang, Yalu River, Tumen River, Suifen River and other river basins in the northeast of China [5]. In recent years, due to overfishing, deterioration of the living environment, and loss of habitat, the distribution area of thinhead salmon has been shrinking, and the population has declined dramatically [6]. Therefore, it is of great theoretical and practical significance to carry out artificial breeding for large-scale farming and species protection of fine scale fish. Seed breeding is a key stage for artificial breeding of fine scale fish, and this period is the period when the body is the most vulnerable, the
disease is the most prone, and the mortality rate is the highest. At present, the research on the Allometry of salmon trout has been reported more at home and abroad [7,8], but the research on fine scales has not been reported. The aim of this study was to understand the priority of organ development and the growth rate of different developmental stages during the low-temperature cultivation process of systemic allelomorphic growth of fine scale fish larvae at low temperature, and to improve the basic data of the early organ development of fine scale fish. It will provide theoretical reference for fine scale fish seed breeding technology and healthy breeding in alpine regions.

2. Materials and Methods

2.1. Experimental Materials
In this experiment, the samples of fine scale fish were from the cold water fish base of Yudu Mountain, Beijing Fisheries Research Institute. The same batch of artificial fertilized eggs were taken and placed in a long strip fiber reinforced plastic incubator tank for continuous water hatching. The incubation water temperature was 4~6 °C and the necrotic eggs were sorted out every day. After breaking the film, the larvae were all floating up.

2.2. Experimental Methods
Optical microscope (NIKON YS100) and dissecting microscope (XTL-2400) were used to observe the early morphological development of larvae and take pictures. During the experiment, 10 larvae were randomly sampled every day from 0-17 days old. MS-222 was anesthetized, and the morphological changes of each organ were observed with a dissecting microscope. The rostrum length, eye diameter, head length, trunk length, tail fin length, total length, body height, yolk-sac length, yolk-sac height, body width, yolk-sac width (Figure 1) were accurate to 0.001 cm. All measurements were measured in parallel or perpendicular to the horizontal axis of the fish body. After observing and taking pictures, all samples were fixed with neutral formaldehyde solution for inspection.

2.3. Data Processing
The relationship between total length and day age uses the Gompertz Logistic equation $y = A/(1 + Be^{-kx})^{[9]}$, $x$ is the day age, $y$ is the total length corresponding to the day age $x$, $A$ is the progressive total length, and $B$ is the scale Constant, $k$ is the maturity index. The allometric model is calculated using the power function equation, that is, the allometric equation $y = ax^{b^{[10]}}$, taking the total length of yolk-sac larvae as the independent variable $x$, $y$ is the corresponding organ length, and $a$ is the y-intercept, $b$ is allometry index. When $b = 1$, it is isokinetic growth, and the growth of the larvae's organs increases in proportion to the total length. When $b > 1$, it is a positive allometric growth, the organs grow faster than the total length. When $b < 1$, it is a negative allometric growth, the organs grow more slowly than total length.

3. Results

3.1. Relationship between Total Length and Age
The growth curve of the total length of the fish with age accords with the Gompertz Logistic equation $y = A/(1 + Be^{-kx})$, and the expression is: $y = 2.6000/(1 + 0.5782e^{-0.0422x})$, $R^2 = 0.9844$, $n = 170$. The total
length of fresh film fish (0 days old) was 1.553 cm, and the total length of growth reached 2.540 cm after 77 days of growth. It can be seen from Figure 2 that the growth rate of the total length of the larval decreases gradually with the increase of the day age.

Figure 2. Allometry Curve and Function of Head Length

3.2. Allometry of Various Parts of the Body

The head length (Figure 2), trunk length (Figure 3), and tail fin length (Figure 4), Body height (Figure 5) of the fine scale fish larvae showed Allometry, but no inflection points appeared. Their allometry index b are 1.2715, 0.7899, 1.5924, 1.0772, respectively. There were significant differences between four allometry index and 1 (P <0.05), where head length and tail fin length were rapid growth, trunk length was slow growth, and body height was constant growth. Before the 21-day-old (total length 2.120 cm), the body width of the newly hatched larvae (Figure 6) gradually increased with the age.

Figure 3. Allometry Curve and Function of Trunk Length

Figure 4. Allometry Curve and Function of Tail Fin Length

Figure 5. Allometry Curve and Function of Body Height
Figure 6. Allometry Curve and Function of Body Width

3.3. Allometry of Head Organs

Allometry index b of rostrum length (Figure 7), eye diameter (Figure 8) and head length (Figure 2) were 1.8175, 0.5439, 1.2715, respectively, and there were significant differences between the three allometry index and 1 (P <0.05), the growth indexes of both organs were significantly greater than 1, indicating that the rostrum length and head length showed significant rapid growth during this period.

Figure 7. Allometry Curve and Function of Rostrum Length

Figure 8. Allometry Curve and Function of Eye Diameter

3.4. Allometry of the Yolk-Sac

Allometry (consumption and absorption) index b (Figure 9) of yolk-sac length, yolk-sac width, and yolk-sac height are -0.9515, -1.4853, -2.4695, respectively. There were significant differences between the absolute values of the three allometry indexes and 1 (P <0.05). The absolute values of the growth indexes of the two indicators of the yolk-sac were significantly greater than 1.

Figure 9. Allometry Curve and Function of Yolk-Sac Size
4. Discussion

Allometry reflects the morphological and phenotypic plasticity of fish during early development in specific environments \cite{11, 12}. It is the result of the interaction of self gene expression and the external environment \cite{13}. It is the developmental characteristics and individual development strategies that fish have retained through long-term evolution in order to improve feeding, avoid enemies, and continue population reproduction. When larvae hatch, some important functional organs that feed and swim preferentially develop and show rapid growth. This special phenomenon of relative growth differences in the growth of various parts of the body exists in many fish, such as \textit{(Miichthys miuy)} \cite{14}, \textit{Cyprinuscparcio} \cite{15}, \textit{Oncorhynchus keta} Walbaum \cite{7}, \textit{Chelon labrosus} \cite{10}. In this study, fine scale fish larvae preferentially develop functional organs such as feeding and movement. The positive Allometry of the head is more obvious than that of the trunk. Fine scale fish larvae maintain preferential development of feeding and swimming organs, and it is a physiological mechanism that evades the enemy and improves the survival rate.

Many studies have shown that the preferential development of the fish head is a common phenomenon in the early development of fish. The preferential development of the head provides growth space for the rapid development of various organs of the head \cite{10}, thereby ensuring that larvae get the best niche in the living environment \cite{16, 17, 18}. In this experiment, fine scale fish larvae grew to 77 days of age, and their head length was growing rapidly, which is consistent with the above conclusions. This indicates that the rapid growth of the larvae's head guarantees the development and improvement of various functional organs of the head (brain, breathing, sensory and feeding organs), and provides a guarantee for its optimal feeding ecological adaptability.

According to the research on the development of fine scale fish larvae, during the early development, the feeding, breathing and swimming organs of larvae have Allometry characteristics. These organs showed rapid development in the early stages of larvae, so that the larvae after membrane emergence could acquire various abilities that are closely related to early survival in the shortest time. This is a developmental feature that has been preserved during long-term evolution of fish. After the rapid development of the above organs was completed early, the larvae's ability to escape enemies and actively feed quickly improved, thereby adapting to the complex and changing external environment. At the same time, the living environment has a synergistic or stimulating or stressing effect on the early preferential growth of fish \cite{19-21}.

5. References

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