Allometric Growth Patterns of Fine Scale Fish Larvae and Its Ecological Significance

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Abstract. Ecological experiment was conducted to study the allometric growth 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, tail fin length and body height are growing at a positive allometric speed, the trunk is growing at a slow speed; in the head organs, the rostrum length, eye diameter and head length are growing at a positive allometric speed; in the swimming organs, tail fin length is positive allometric growth; yolk sac length, yolk sac width and yolk sac height are positive allometric growth 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

During the early growth and development of fish, affected by genetic factors and environmental factors, the growth of functional organs of the larvae's body is asynchronous, that is, Allometric growth [1,2]. 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].

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 allometric growth 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 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.

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 9~12°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 allometric growth 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: $y=2.5000 / (1+0.2773e^{-0.0468x})$, $R^2=0.9693$, n=255. The total length of fresh film fish (0 days old) was 1.969 cm, and the total length of growth reached 2.468 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.
3.2. Allometric Growth 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 allometric growth, but no inflection points appeared. Their allometric growth index $b$ are 1.3276, 0.7941, 2.5405, 1.1708, respectively. There were significant differences between four allometric growth index and 1 ($P < 0.05$), where head length, tail fin length and body height were rapid growth, and trunk length was slow growth. Before the 17-day-old (total length 2.234 cm), the body width of the newly hatched larvae (Figure 6) gradually increased with the age.

Figure 2. Allometric growth curve and function of head length of fine scale fish

Figure 3. Allometric growth curve and function of trunk length of fine scale fish

Figure 4. Allometric growth curve and function of tail fin length of fine scale fish

Figure 5. Allometric growth curve and function of body height of fine scale fish
3.3. Allometric Growth of Head Organs

Allometric growth index $b$ of rostrum length (Figure 7), eye diameter (Figure 8) and head length (Figure 2) were 1.9956, 1.5505, 1.3276, respectively, and there were significant differences between the three allometric growth 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: Allometric growth curve and function of rostrum length of fine scale fish](image1)

$$y = 0.0147x^{1.9956}$$
$$R^2 = 0.9423$$

![Figure 8: Allometric growth curve and function of eye diameter of fine scale fish](image2)

$$y = 0.0468x^{1.5505}$$
$$R^2 = 0.924$$

3.4. Allometric Growth of the Yolk-Sac

Allometric growth (consumption and absorption) index $b$ (Figure 9) of yolk-sac length, yolk-sac width, and yolk-sac height are -1.3132, -2.4791, -3.6859, respectively. There were significant differences between the absolute values of the three allometric growth indexes and 1 ($P < 0.05$). The absolute values of the growth indexes of the three indicators of the yolk-sac were significantly greater than 1, and it showed that the yolk-sac showed obvious rapid consumption and absorption during this period, but no growth inflection point appeared.

![Figure 9: Allometric growth curve and function of yolk-sac length of fine scale fish](image3)

$$y = -0.2444x^2 + 1.1179x - 1.1356$$
$$R^2 = 0.3645$$

![Figure 10: Allometric growth curve and function of yolk-sac width of fine scale fish](image4)

$$y = -0.2444x^2 + 1.1179x - 1.1356$$
$$R^2 = 0.3645$$

![Figure 11: Allometric growth curve and function of yolk-sac height of fine scale fish](image5)

$$y = -0.2444x^2 + 1.1179x - 1.1356$$
$$R^2 = 0.3645$$
Figure 9. Allometric growth curve and function of yolk-sac size of fine scale fish

4. Discussion
In most osteochondids, early development and organ differentiation of larvae are extremely important and complex processes, including changes in morphogenesis, body shape, metabolism in the body, and life behavior \[11, 12\], all of which are external to the outside world. The adaptive choice of the harsh living environment, and this choice is mainly reflected in the rapid development of some functional organs such as sensory, feeding, swimming, etc. during the early development of larvae. In this study, fine scale fish larvae preferentially develop functional organs such as feeding and movement. The positive allometric growth 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 \[13\], thereby ensuring that larvae get the best niche in the living environment \[14,15,16\]. In this experiment, fine scale fish larvae grew to 57 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.

Studies by Ma, et al. \[17\] and Zhuang, et al. \[18\] show that the eye, as an important sensory organ, completes the fastest growth stage as early as \[19\]. In this study, the eye diameter of fine scale fish larvae has been faster than the total length growth rate in order to improve the ability to forage and avoid enemies as soon as possible. However, the growth rate is smaller than the rostrum length, indicating that the importance of the eyes is lower than the rostrum length in the early development stage of the salmon, which may be related to the environment in which it grows.

According to the early development characteristics and environmental adaptability of fish, in the artificial breeding of seed production, the growth conditions at the early stage of development should be used to create the physiological environmental conditions required for them, and appropriate opening foods should be fed to give priority to important organs. Development, in order to effectively obtain exogenous nutrition and pass the dangerous period, to avoid early death; in the natural breeding process of wild fish, by protecting its spawning ground, creating a good hatching and early development environment, it is important Ecological significance.

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