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RESEARCH ARTICLE

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# Effects of prey density on the growth and survival of hybrid snakehead larvae



**Abstract** The effects of prey density (0.1, 0.3, 1, 3 and 10 prey·mL$^{-1}$) on the growth and survival of hybrid snakehead (*Channa argus* × *C. maculate*) larvae were investigated. The larvae were divided into three groups with different body lengths of 0.68 cm, 1.50 cm and 3.20 cm, respectively. The growth of the hybrid snakehead larvae in all three groups increased with prey density increasing from 0.1 to 1 prey·mL$^{-1}$. The specific growth rate (SGR) was the highest when the prey density was 1 prey·mL$^{-1}$. When prey density was higher than 1 prey·mL$^{-1}$, SGR of larvae in Group I (the larvae of early development stage) decreased, while no significant change was observed in those of Group II and Group III. The survival rates of hybrid snakehead larvae in all three groups were high (91.11%–100%) and not significantly affected by the prey densities except in Group I with the highest prey density (10.0 prey·mL$^{-1}$) which was significantly lower than the others. Body size was not sensitive to prey density. The optimum prey density was confirmed at 1 prey·mL$^{-1}$ in all the treatments.

**Keywords** hybrid snakehead, larvae, growth, survival, prey density

## 1 Introduction

Due to its great advantages of heterosis in commercial fish farming, high growth rate, strong resistance to disease, high economic benefit, etc, hybrid snakehead (*Channa argus* ♂ × *C. maculate* ♀) became one of the most popular species cultured in Southern China, especially in the region of the Pearl River Delta. Therefore, the requirement for the fingerling hybrid has increased quickly and the breeding scale has expanded yearly.

For most fish, larval period is considered as the most crucial phase of their entire life cycle (Johnston and Mathias, 1994). During this period, the fish will complete the nutrition change from endogenous to exogenous. If palatable prey is not sufficient, a high mortality of the larvae could occur (Houde and Schekter, 1980; Klumpp and Von Westernhagen, 1986). Therefore, it's very important to provide the larvae with a prey of appropriate species, size and density. There are interspecific differences in the impacts of prey densities on the growth and survival rate of larvae. For example, the growth and survival of place larvae (Wyatt, 1972), hadhock larvae (Laurence, 1974) and herring larvae (Werner and Blaxter, 1980; Munk and Kiørboe, 1985) increased with the increasing of prey densities and reached their asymptotes. The study with Atlantic cod larvae, however, showed that there was an optimum prey density at which the growth rate and survival rate were highest (Puvanendran and Brown, 1999). The objective of our survey was to investigate the effects of prey density on the growth and survival of hybrid snakehead larvae, and thereafter provide a reference for the commercial production of hybrid snakehead larvae.

## 2 Materials and methods

### 2.1 Experimental fish

Paternal fish (*Channa argus* ♂) were obtained from suburbs of Wuhan, and the female parent (*C. maculate* ♀) was obtained from Shunde city, Guangdong Province. After in vitro fertilization, fertilized eggs were cultivated in our laboratory, and the larvae were reared in cement ponds (1 m × 2 m × 1 m).

The experiment covered the whole larvae period of hybrid snakeheads, but the larvae were divided in three groups based on their developmental stages. Initial body weight and total length for larvae in Group I (larvae of

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early stage, first feeding larvae, 3 d after hatching) were (0.0025 ± 0.0002) g and (0.68 ± 0.01) cm, respectively. Those for Group II (larvae of middle stage, 8 d after hatching) were (0.035 ± 0.001) g and (1.50 ± 0.01) cm, respectively, and for Group III (larvae of later stage, about 18 d after hatching) were (0.273 ± 0.002) g, (3.20 ± 0.02) cm, respectively. The larvae from the same patch of fertilized eggs were used in each group.

## 2.2 Experimental device

The experiment was conducted in white aquariums (52 cm × 34 cm × 24 cm). Each aquarium contained 30 L of water, with a water depth of 17 cm. All the aquariums were fixed in a cement pond (4 m × 6 m × 1 m) with water depth of 25 cm. The pond water was heated with heating bonds and the water temperature was kept at (26 ± 1.5)°C. The water used in the experiment was filtered lake water, with ammonia concentration of (0.02 ± 0.01) mg·L$^{-1}$, pH value of (6.8 ± 0.1) and dissolved oxygen of (6.8 ± 0.7) mg·L$^{-1}$.

The experiment was carried out under a natural photoperiodic regime. The pond was shaded with a net when the sunshine was too strong.

## 2.3 Experimental methods

Hybrid snakehead larvae were divided into three groups with different body sizes, and each group was fed with live zooplankton. Prey densities were assigned to 0.1, 0.3, 1.0, 3.0 and 10.0 preys per milliliter with three replicates. There were a total of 15 aquariums for each group and each aquarium contained 30 larvae.

Live zooplankton were caught daily from a lake with a zooplankton net (mesh size 0.10 mm) and transported to the laboratory in oxygenated PE bags. Then, the large zooplankton and debris were sieved out with a sieve (mesh size 0.17 mm), and the filtrate were poured into a big container filled with clean water. The live zooplankton were collected with a small plate and then transferred into another container. The larvae in Group II and Group III were fed with relatively larger zooplanktons (0.13–0.17 mm, filtered out using a net with mesh size of 0.13 mm), and larvae in Group I were fed with smaller (0.10–0.13 mm) ones.

Three liters of water was siphoned out equally from different parts of the aquarium, the surface layer, middle, bottom and corners, for the inspection of prey density. Then, when necessary, the prey density in each aquarium was adjusted by adding the corresponding quantity of zooplankton to keep it at the constant level. The adjustment was made at least twice daily, usually at 7:00 am and 7:00 pm. In order to monitor the extent of zooplankton reduction, the zooplankton densities in the aquaria with prey densities at 0.1 mg·L$^{-1}$ and 0.3 mg·L$^{-1}$ were checked once every 2 hours for 12 hours. The result showed that there was 55% of zooplankton left 12 hours after feeding (Fig. 1).

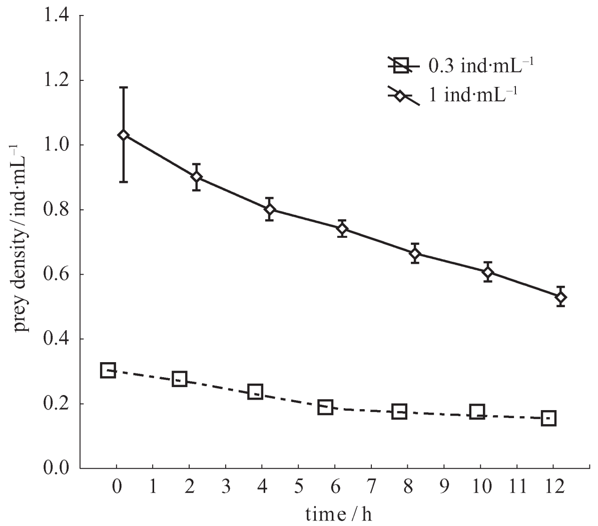


**Fig. 1** Changes of prey density after feeding

Feces, residues and dead larvae were siphoned out every morning during the test. The water was replaced twice a day, thoroughly in the morning and half in the evening.

The experiment was carried out from the 1st to the 13th of June, 2006. For each group, it lasted for 3 days. At the end of experiment for Group I, the body weight and body length were measured and the survival rate was calculated. Then, tests for Group II and Group III were conducted. After absorbing water with absorbent paper with an electric balance (0.0001 g), the total body weight (with a precision of 0.1 mg) of all the larvae in each aquarium was weighed. The total lengths (precision 0.1 mm) of ten larvae from each aquarium were measured with vernier calipers after anesthesia treatments with MS-222.

## 2.4 Data processing and statistical analysis

At the end of the test, the body weight and total length of larval hybrid were measured. The survived larvae were counted for calculating their survival rate (SR). Growth performance was evaluated with the indices of specific growth rate (SGR), growth rate of total length (GBL) and the growth rate of body weight (GBW). All the formulas used are as follows:

$$SGR\ (\%\cdot d^{-1}) = (\ln W_t - \ln W_0)/t \times 100,$$
$$GBL\ (\%) = (L_t - L_0)/L_0 \times 100,$$
$$GBW\ (\%) = (W_t - W_0)/W_0 \times 100,$$
$$SR\ (\%) = (N_t/N_0) \times 100,$$

where $L_0$ means the initial total length of larva; $L_t$ means the final total length; $W_0$ and $W_t$ mean the initial and final body weight, respectively; $N_0$ is the number of larvae stocked in each aquarium at the beginning of the experiment and $N_t$ is the number of larvae survived at the end of the experiment; and $t$ means the duration of the experiment in days.

Experimental data were analyzed with STATISTICA (Version 6.0). One-way analysis of variance was used to examine the differences in growth. Comparisons of mean values were made using Fisher's least significant difference test (SAS, 1987). A significance level of $P < 0.05$ was used for all statistical tests.

## 3 Results

### 3.1 Effects of prey density on the growth of hybrid snakehead larvae

The SGRs of larvae hybrid snakehead in all groups increased when the preydensity increased from 0.1 prey·mL$^{-1}$ to 1 prey·mL$^{-1}$, and reached their maximum at the prey density of 1.0 prey·mL$^{-1}$. In Group I, the SGR of the larvae with prey density of 0.1 prey·mL$^{-1}$ was 35.33, and 50.63 for 1.0 prey·mL$^{-1}$. The SGRs of larvae in Group II with prey densities of 0.1 prey·mL$^{-1}$ and 1.0 prey·mL$^{-1}$ were 15.41 and 31.97, respectively, and those in Group III were 15.13 and 21.82, respectively. By further increasing of the prey density (from 1.0 prey·mL$^{-1}$ to 10.0 prey·mL$^{-1}$), the SGR of the larvae in Group I decreased, and those in Group II and Group III had no significant changes. (Fig. 2)

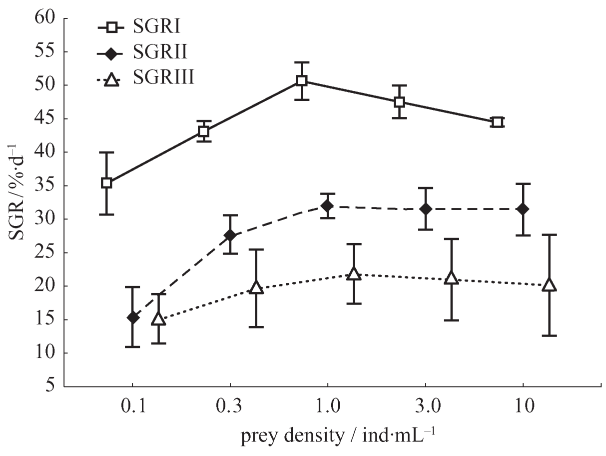


**Fig. 2** Effects of prey density on SGR of hybrid snakehead larvae

The results of variance analysis showed that there were significant differences among the SGRs of larvae between adjacent prey densities in Group I. In Group II, significant differences of SGRs were found between the larvae fed with prey densities of 0.1 prey·mL$^{-1}$ and 0.3 prey·mL$^{-1}$, 0.3 prey·mL$^{-1}$ and 1.0 prey·mL$^{-1}$, but not found among larvae fed with prey densities of 1.0, 3.0 and 10.0 prey·mL$^{-1}$. In Group III, the SGRs of larvae fed with prey density of 0.1 prey·mL$^{-1}$ were significantly different from those with other prey densities, but there was no significant differences among the SGRs of larvae fed with prey densities of 0.3, 1.0, 3.0 and 10.0 prey·mL$^{-1}$. The trends in final body weights, final total lengths, GBLs and GBWs were the same as that in the SGR (Table 1).

### 3.2 Effects of prey density on survival rate of hybrid snakehead larvae

In Group II and Group III, the survival rates of larvae fed with different prey densities were all 100%. In Group I, the survival rates of larvae fed with prey densities of 0.1, 0.3, 1.0 and 3.0 prey·mL$^{-1}$ fluctuated between 96.67% and 98.89%, and there were no significant differences among them. However, the survival rates of larvae fed with prey density of 10.0 prey·mL$^{-1}$ were significantly lower than those of the other prey densities (Table 1 and Fig. 3). This indicates that over crowded prey items will reduce the survival rate of hybrid snakehead larvae.

## 4 Discussion

There are three different results reported in literatures dealing with the effects of prey density on the growth and survival of larval fish: (1) The growth rate and survival rate increase with the increasing prey density, and asymptotes are reached, such as in place larvae (Wyatt, 1972), hadhock larvae (Laurence, 1974), herring larvae (Werner and Blaxter, 1980; Munk and Kiørboe, 1985) and perch larvae (Wang and Echmann, 1999). (2) There is no relationship between the prey density and the growth rate of larvae. Yamashita and Bailey (1989) reported that prey density had no effect on the growth and survival of walleye pollock larvae. Temple (2004) reported that the rotifer density (5, 10, 20 and 30 rotifer·mL$^{-1}$) had no effect on the growth of larval fat snook. (3) There is an optimum prey density, i.e. as the prey density increases, the growth rate of larvae increases, reaches a peak, and then drops (Kestemont and Awaiss, 1989; Brown and Taylor, 1992; Johnson and Dropkin, 1995; Parra and Yúfera, 2002). Parra and Yúfera (2002) found that the growth rate of gilthead seabream larvae were similar when fed with 0.1 rotifer·mL$^{-1}$ and 1.0 rotifer·mL$^{-1}$ but decreased when fed with 10.0 rotifer·mL$^{-1}$. These may result from experimental design other than species difference.

The results of our experiment showed that there is an optimum prey density, 1.0 prey·mL$^{-1}$, for hybrid snakehead larvae at early development stage (larvae of Group I), which is consistent with the 3rd proposition; while the

**Table 1** Growth indicators of hybrid snakehead larvae fed with different prey densities (M ± *sd*)

| growth indicators | groups | prey density/prey·$mL^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | 0.1 | 0.3 | 1 | 3 | 10 |
| final weight/g | I | 0.007 ± 0.000 $^{a}$ | 0.009 ± 0.000 $^{b}$ | 0.012 ± 0.001 $^{d}$ | 0.011 ± 0.000 $^{c}$ | 0.010 ± 0.000 $^{b}$ |
| | II | 0.056 ± 0.003 $^{a}$ | 0.081 ± 0.002 $^{b}$ | 0.092 ± 0.001 $^{c}$ | 0.091 ± 0.003 $^{c}$ | 0.091 ± 0.003 $^{c}$ |
| | III | 0.43 ± 0.02 $^{a}$ | 0.49 ± 0.03 $^{b}$ | 0.52 ± 0.02 $^{b}$ | 0.51 ± 0.03 $^{b}$ | 0.50 ± 0.04 $^{b}$ |
| final length/cm | I | 0.89 ± 0.04 $^{a}$ | 0.95 ± 0.01 $^{b}$ | 1.02 ± 0.04 $^{c}$ | 0.98 ± 0.01 $^{b}$ | 0.96 ± 0.01 $^{b}$ |
| | II | 1.79 ± 0.02 $^{a}$ | 1.98 ± 0.05 $^{b}$ | 2.10 ± 0.05 $^{c}$ | 2.10 ± 0.03 $^{c}$ | 2.07 ± 0.05 $^{c}$ |
| | III | 3.42 ± 0.01 $^{a}$ | 3.63 ± 0.04 $^{b}$ | 3.74 ± 0.02 $^{c}$ | 3.71 ± 0.06 $^{bc}$ | 3.68 ± 0.02 $^{bc}$ |
| GBW/% | I | 189.79 ± 29.22 $^{a}$ | 264.83 ± 6.70 $^{b}$ | 359.03 ± 12.36 $^{d}$ | 319.02 ± 10.99 $^{c}$ | 279.66 ± 2.90 $^{b}$ |
| | II | 58.93 ± 8.54 $^{a}$ | 129.77 ± 8.03 $^{b}$ | 161.01 ± 5.70 $^{c}$ | 157.74 ± 9.61 $^{c}$ | 158.25 ± 11.64 $^{c}$ |
| | III | 57.54 ± 5.74 $^{a}$ | 80.85 ± 10.35 $^{b}$ | 92.62 ± 8.52 $^{b}$ | 88.03 ± 11.10 $^{b}$ | 83.41 ± 13.73 $^{b}$ |
| GBL/% | I | 29.20 ± 5.13 $^{a}$ | 38.96 ± 1.07 $^{b}$ | 49.19 ± 2.86 $^{c}$ | 43.53 ± 0.42 $^{b}$ | 44.47 ± 0.26 $^{b}$ |
| | II | 18.19 ± 1.72 $^{a}$ | 31.92 ± 3.68 $^{b}$ | 40.10 ± 3.46 $^{c}$ | 39.79 ± 2.09 $^{c}$ | 38.14 ± 3.63 $^{bc}$ |
| | III | 6.99 ± 0.30 $^{a}$ | 13.73 ± 1.09 $^{b}$ | 16.96 ± 0.53 $^{c}$ | 15.67 ± 1.85 $^{bc}$ | 14.71 ± 0.72 $^{bc}$ |
| SR/% | I | 98.89 ± 1.92 $^{b}$ | 96.67 ± 3.33 $^{b}$ | 98.89 ± 1.92 $^{b}$ | 96.67 ± 3.33 $^{b}$ | 91.11 ± 1.92 $^{a}$ |
| | II | 100 | 100 | 100 | 100 | 100 |
| | III | 100 | 100 | 100 | 100 | 100 |
| SGR/%·$d^{-1}$ | I | 35.33 ± 1.43 $^{a}$ | 43.14 ± 0.61 $^{b}$ | 50.63 ± 1.12 $^{d}$ | 47.53 ± 0.98 $^{c}$ | 44.47 ± 0.26 $^{b}$ |
| | II | 15.41 ± 1.50 $^{a}$ | 27.72 ± 1.16 $^{b}$ | 31.97 ± 0.73 $^{c}$ | 31.54 ± 1.26 $^{c}$ | 31.44 ± 1.55 $^{c}$ |
| | III | 15.13 ± 1.21 $^{a}$ | 19.70 ± 1.90 $^{b}$ | 21.82 ± 1.46 $^{b}$ | 20.99 ± 2.00 $^{b}$ | 20.13 ± 2.48 $^{b}$ |

Note: The data (M ± *sd*) in the same line with different superscripts means significant difference at a $P < 0.05$ level.

growth rate of hybrid snakehead larvae at later development stage (larvae of Group II and Group III) increased as the prey density increased and reached an asymptotic value, which is consistent with the 1st. As to the 2nd, the lowest prey density (5.0 rotifer·$mL^{-1}$) could be higher than the optimum value. For instance, if the prey densities for Group III in this experiment were set as 1.0, 3.0 and 10.0 prey·$mL^{-1}$, the result would be consistent with it.

Parra and Yúfera (2002) gave an explanation to the optimum prey density saying that lower prey density will enhance feeding efficiency. In this experiment, when the prey density surpassed the optimum density, the growth rate of hybrid snakehead larvae at early developmental stage (Group I) dropped significantly; when the prey density was 10.0 prey·$mL^{-1}$, the survival rate dropped significantly, too. While for the larvae at later development stages (Group II and Group III), further increase of prey density had no influence on the growth and survival of the larvae. With the increase of prey density,

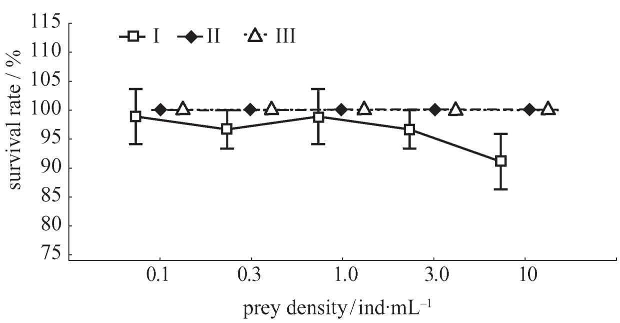


**Fig. 3** Effects of prey density on survival rate of hybrid snakehead larvae

zooplankton consumed more oxygen, and excreted more metabolites. These may result in the decline of growth and survival of larvae at early developmental stages. As the larvae grew, their resistance to environmental impacts improved, higher prey densities (3.0 prey·$mL^{-1}$ and 10.0 prey·$mL^{-1}$) will not reduce their growth rate and survival rate.

In all the three tested groups, the growth rate and survival rate of the larvae reached the maximum at the prey density of 1.0 prey·$mL^{-1}$. So, the optimum prey density for commercial production of hybrid snakehead larvae is considered to be 1.0 prey·$mL^{-1}$.

Ljunggren (2002) investigated the effects of prey density on the growth and survival of pikeperch larvae with different body sizes and found that the requirement for prey density varied greatly with the body size. In order to keep the SGR at 0, the prey density for the 6.5 mm larval pikeperch needs to be over 585 prey·$mL^{-1}$, 55 prey·$mL^{-1}$ for the 7-mm larvae, and less than 10 prey·$mL^{-1}$ for the 11-mm larvae. In our experiment, the optimum prey density for all three groups was the same, indicating that the body size (developmental stage) of hybrid snakehead larvae had no effect on the optimum prey density. This may result from the species difference. Larvae of some species may forage at the first day of hatching, some may forage at the 7th day after hatching or even later. The larvae with large yolk-sac will have more nutrients for early development and will be healthy at first feeding. Then, the difference of feeding ability between the larvae of earlier stage (small size) and later stage (large size) may be small. Hybrid snakehead larvae have a large yolk-sac and its first feeding is at the 4th day of hatching. So the body size of the larvae has no effect on the optimum prey density.

Because the first feeding of pikeperch larvae is at the 2nd day of hatching, larval body size will have a great influence on the prey density it requires.

In our experiment, there was no significant difference in survival rate of hybrid snakehead larvae in all the three tested groups fed at different prey densities, except in the group with prey density of 10.0 prey·$mL^{-1}$ which was significantly lower than that of the others. This is similar to the result of Temple (2004). The high survival rate of the first feeding larvae indicated that the yolk-sac of hybrid snakehead larvae will provide sufficient nutrients for its early development and the larvae was strong enough to feed actively at first feeding. This suggests that the prey density is not the main cause for the low survival rate of hybrid snakehead larvae in its commercial production.

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