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Original Research Articles

Study on Individual Fecundity of *Hemibarbus medius* in Beiliu River

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Fish individual fecundity is an important factor governing fish replenishment and population dynamics. An in-depth understanding of the dynamics of fish fecundity is not only important for the study of fish and fisheries ecology but also of great practical significance. From mid-February to early March 2023, we collected 99 samples of *Hemibarbus medius* in the Beiliu River and analyzed their body length, body weight, empty shell weight, and gonadal weight. Using the weighing mass method, we calculated the absolute fecundity of each individual, relative fecundity in terms of the body length and weight, gonadosomatic index, and Fulton's condition factor. We used six mathematical models to fit the relationship between individual fecundity and the biological indicators of *H. medius*. The study demonstrated that the female-to-male ratio in the samples was 1.06:1, and the minimum age for sexual maturity was observed as 1^+ and 0^+ years old for females and males, respectively. Furthermore, the body lengths of females with gonadal development of stage IV or above ranged from 11.5 to 25.7 cm, while their body weights ranged from 24.04 to 263.42 g. The absolute fecundity of individuals varied significantly, ranging from 195 to 14,044 eggs. The relative fecundity of the lengths was between 17 to 624 eggs/cm, while the relative fecundity of the body weights ranged from 5 to 76 eggs/g. This study established that absolute fecundity exhibits power function correlations with various biological indicators except for parabolic correlation with Fulton's condition factor of *H. medius*, whereas body length relative fecundity demonstrates power function correlations with all biological indicators except parabolic correlations with empty shell weight and Fulton's condition factor. Notably, body weight relative fecundity displays significant correlations only with the gonadosomatic index. These findings are crucial in accurately estimating the population size of *H. medius* in Beiliu River and its change pattern. In addition, these findings provide a foundation for resource management and rational utilization of *H. medius* in the Beaulieu River.

INTRODUCTION

Fecundity refers to the absolute or relative number of eggs that may expelled by females during the breeding season, which is a crucial indicator of reproductive biology. Fish fecundity can be divided into individual absolute fecundity and relative fecundity. Both genetic and environmental factors play a crucial role in determining the fecundity of fish.[1] Additionally, fecundity is the basis for maintaining the stability of fish populations and ensuring the survival of the species. Thus, studying the fecundity of fish is of great practical significance for understanding population dynamics and germplasm conservation.[2]

Hemibarbus medius is widely distributed in most aquatic systems in China. It tends to inhabit the lower-mid layers of water, and is often caught by fishing gear such as gill nets, cast nets and ground cages.[3] *H. medius* is characterized by tender meat, tasty flavor, rich nutrition and high yield, and has certain economic and food value. In recent years, the construction of water conservancy facilities in the Beiliu River, along with ecological damage and overfishing, has affected the living environment of the Beiliu River, resulting in a decline in the number of wild fish resources. Although there have been studies on the fecundity of *H. medius*,[4] there has not been a systematic study of the relationship between individual fecundity and biological indicators of *H. medius*. This study utilized 99 *H. medius* collected in Beiliu River from mid-February to early March 2023 to investigate the reproductive group structure and the correlation between body length and body weight of *H.*

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medius. From these samples, 39 females whose gonadal development had reached stage IV or above were selected to study the relationship between individual fecundity of *H. medius* and their biological indexes. This study aims to provide basic information for the expansion, conservation and usage of *H. medius* resources in Beiliu River.

MATERIALS AND METHODS

SAMPLING AND MEASUREMENT

Every day between mid-February to early March 2023, healthy and active *H. medius* were purchased from fishermen's catches in the Beiliu River (N23°22′, E110°54′). A total of 99 fish samples were collected. First, the external morphology of *H. medius* was observed, followed by measurement of total length (TL, with an accuracy of 1 mm), body length (L, with an accuracy of 1 mm) and body weight (W, with an accuracy of 0.01 g) of all the individuals using a vernier caliper and a table balance. Finally, the Fulton's condition factor (K) was calculated. All samples were dissected and gonads of female *H. medius* were removed. The gonad weight (GW) and empty shell weight (BW) were measured using the table balance with an accuracy of 0.01 g, followed the gonadosomatic index (GSI) were calculated. Ten scales from the midsection above the lateral line to the lower part below the first half of the dorsal fin were used as age-identification materials. The gonadal staging was based on the method of Ye and Zhang,[5] which divided the gonadal development process of female fish into six periods, and the ovaries of 39 of these females whose gonadal development had reached stage IV and above were selected and weighed for their ovary weight. Subsequently stored in 10% formalin solution. A total of 39 ovaries were used for fecundity estimation. Given this, a sub-sample of 0.05 g was taken from each of 6 portions (the anterior, middle, and posterior of both lobes) and counted number of eggs under a stereo microscope. The absolute fecundity (*F*) was calculated using the equation, $F = ((Nss \times Wo)/Wss)$ with N_{ss} = number of oocytes in 6 subsamples, W_o = total weight the ovary, W_{ss} = total weight of 6 subsamples.[6]

CALCULATION FORMULAS OF BIOLOGICAL INDEXES

The relationship between body weight and body length, and Fulton's condition factor of male and female *H. medius were* evaluated as follows:

$$\text{Relationship between body weight (W) and body length (L)} : W = a \times L^b$$

$$\text{Fulton's condition factor (K)} = \left(\frac{W}{L^3}\right) \times 100$$

Gonadosomatic index (GSI), relative fecundity in body length (F_L) and relative fecundity in body weight (F_W) of female *H. medius* were determined using the follow equations:

$$\text{Gonadosomatic index (GSI)} = \frac{Gonad\ weight\ (GW)}{empty\ shell\ weight\ (BW)}$$

$$\text{Relative fecundity in body length}\ (F_L) = \frac{F}{L}$$

$$\text{Relative fecundity in body weight}(F_W) = \frac{F}{W}$$

DATA ANALYSIS

All data were analyzed using Excel2022 and Origin2022 software, and $P < 0.05$ was considered as significant correlation. Six mathematical models, including linear, quadratic, logarithmic, power, exponential and inverse functions, were used to fit the relationship between individual fecundity and each biological index, and the one with the largest correlation coefficient (R) was selected as the fitting function.

ETHIC COMMITTEE

All experimental protocols were approved by the Institutional Animal Care and Use Committee (IACUC) of Southwest University in China, and the approval code is swu-20230215207. This research followed all state and institutional guidelines for the care and use of animals.

RESULTS

POPULATION STRUCTURE OF *H. MEDIUS* IN BEILIU RIVER

Among the 99 samples from the Beiliu River, female *H. medius* accounted for 51, and male *H. medius* accounted for 48, with a sex ratio of 1.06:1, and the number of males was less than that of females. In addition, among 66 sexually mature individuals, females accounted for 43 and males accounted for 23, with a sex ratio of 1.87:1, and the number of males was significantly less than that of females.

Among females and males reached sexual maturity, the minimum age was 1^+ in females and 0^+ in males, respectively. The minimum individuals in females reached sexual maturity weighed 45.62 g, with a total length of 18.5 cm, a body length of 15.3 cm, and a Gonadosomatic index of 8%. The minimum individual in males reached sexual maturity weighed 31.85 g, with a total length of 15.4 cm, a body length of 12.6 cm, and a Gonadosomatic index of 0.35%.

As shown in Table 1, the age of dominant groups in the female population was age-2^+, followed by age-1^+ and age-2, which accounted for 33.3%, 21.6% and 19.6% in the total female population, respectively. The age of dominant groups in the male population were age-2 and age-2^+, followed by age 1^+, which accounted for 25%, 25% and 18.6% in the total male population, respectively.

INDIVIDUAL FECUNDITY OF *H. MEDIUS* IN BEILIU RIVER

In this research, 39 female *H. medius* with gonadal development of stage IV and above were observed, with body length ranged from 11.5 to 25.7 cm, body weight ranged from 24.04 to 263.42 g, and age ranged from 0^+ to 3^+ years old. The absolute fecundity of *H. medius* ranged from 195 to 14044 eggs, with an average of 5020 eggs per individual. The relative fecundity in body length (F_L) of *H. medius* ranged from 17 to 624 eggs per centimeter, with an average

Table 1. The body length and body weight in different age groups of *H. medius*.

Sex	Age	Number	Body length		Body weight	
			Range	Mean ± SD	Range	Mean ± SD
Male	0^+	7	11.2-15.1	13.23±2.1	20.20-60.98	34.31±17.32
	1	7	11.8-19.2	13.33±2.66	22.81-102.15	38.63±28.36
	1^+	9	12.8-18.7	16.53±2.08	32.47-118.10	74.84±28.41
	2	12	14.1-21.2	17.75±2.24	38.94-166.34	93.55±37.77
	2^+	12	16.4-22.2	19.18±1.54	64.54-182.47	128.33±33.31
	3	1	20.2	/	131.16	/
Female	0^+	2	11.5-12.5	12.00±0.71	24.04-28.63	26.34±3.25
	1	2	11.5-15.6	13.55±2.9	24.94-47.80	36.37±16.16
	1^+	11	15.3-21.0	18.16±1.75	45.62-139.15	92.46±30.89
	2	10	15.4-22.5	19.42±2.29	59.53-169.43	114.02±41.08
	2^+	17	16.5-22.5	19.86±1.44	86.12-199.78	133.99±31.09
	3	5	17.9-23.7	19.76±2.31	97.70-204.13	134.72±42.06
	3^+	4	21.5-25.7	23.33±2.06	166.38-263.42	209.91±49.72

Table 2. The contribution rate of sexual maturity females in different age groups for reproduction.

Age group (age)	Matured female (tail)	Matured female ratio (%)	Fecundity on average (egg)	Total fecundity (egg)	Contribution rate (%)
1^+	10	26.32	5091±3128	50911	26.03
2	9	23.68	4039±2231	36352	18.59
2^+	15	39.47	5359±3274	80386	41.10
3	3	7.89	7714±1056	23142	11.83
3^+	1	2.63	4782	4782	2.45

of 253 eggs per centimeter. In addition, the relative fecundity in body weight (F_W) of *H. medius* ranged from 5 to 76 eggs per gram, with an average of 41 eggs per gram. To evaluate the contribution of breeding groups to population replenishment, we calculated the proportion of the eggs number in different age groups accounted for in all breeding groups of the *H. medius* (Table 2). According to the results, the age-2^+ breeding group had the largest contribution to the population with a proportion of 41.10%, followed by the age-1^+ breeding group, with a contribution rate of 26.03%. The number of age-1^+ and age-2^+ groups accounted for 26.32% and 39.47% of the total number of females in the sexually mature group, respectively, which is the reason for their relatively high contribution rate. The number of females in the age-3 group only accounted for 7.89% of the total number of sexually mature females, while the contribution rate was 11.83%, indicating that the age-3 breeding group has the high potential for fecundity.

RELATIONSHIP BETWEEN FECUNDITY AND BODY LENGTH (L), BODY WEIGHT (W) OF *H. MEDIUS*

Figure 1a and Figure 1c show the relationship between absolute fecundity (F) and body length (L), body weight (W) of *H. medius*, respectively, which indicates that the *H. medius* absolute fecundity increased both with its body length and body weight. The power function between absolute fecundity (F) and body length (L) of *H. medius* was $F = 16.5178L^{1.9261}$ ($R = 0.4263$, $P < 0.01$), while the power function $F = 14.774W^{1.1771}$ ($R = 0.5263$, $P < 0.01$) represents the relationship between absolute fecundity (F) and body weight (W). Similarly, *H. medius* relative fecundity (F_L) also increased with the body length (Fig. 1b) and body weight (Fig. 1d), and the power function between relative fecundity (F_L) and body length was $F_L = 0.0668L^{2.7064}$ ($R = 0.4443$, $P < 0.01$), the power function between relative fecundity (F_L) and body weight was $F_L = 17.0198W^{0.5665}$ ($R = 0.4290$, $P < 0.01$).

RELATIONSHIP BETWEEN FECUNDITY AND EMPTY SHELL WEIGHT (BW), GONADAL WEIGHT (GW) OF *H. MEDIUS*

According to the results, the absolute fecundity (F) both increased with the empty shell weight (Fig. 2a) and gonadal weight (Fig. 2c), respectively. The power function $F = 20.24BW^{1.1457}$ ($R = 0.5756$, $P < 0.01$) represents the relationship between absolute fecundity (F) and empty shell weight (BW), and $F = 661.86GW^{0.8249}$ ($R = 0.6899$, $P < 0.01$) represents the relationship between absolute fecundity (F) and gonadal weight (GW). In addition, there was a parabolic correlation between the relative fecundity (F_L) and the

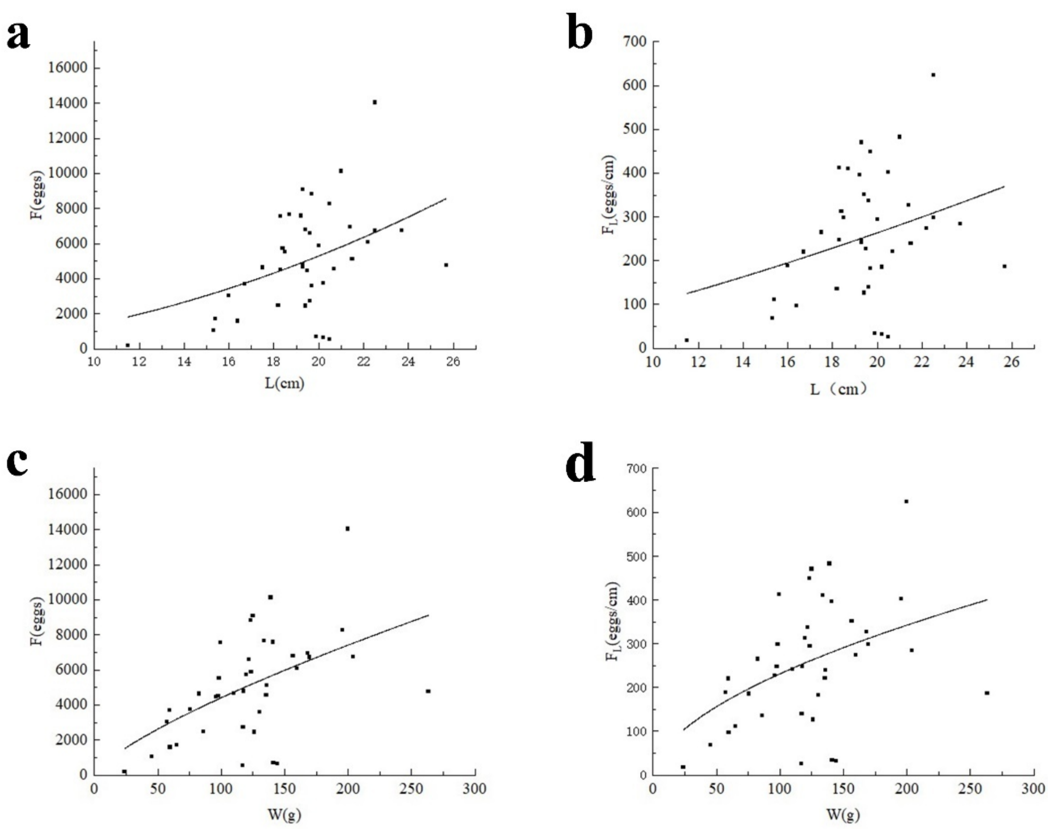

Figure 1. The relationship between fecundity and body length, body weight of *H. medius*: (a) relationship between absolute fecundity (F) and body length (L), (b) relationship between relative fecundity (F_L) and body length (L), (c) relationship between absolute fecundity (F) and body weight (W), (d) relationship between relative fecundity (F_L) and body weight (W).

empty shell weight (BW) in *H. medius* (Fig. 2b). The equation was F_W = -0.0139BW^7 + 4.633BW - 58.827 (R = 0.4982, P < 0.01). And figure 2d shows that the relationship between relative fecundity (F_L) and gonadal weight (GW) can be represented by the power function $F_L = 44.536GW^{0.7042}$ (R = 0.6378, P < 0.01).

RELATIONSHIP BETWEEN FECUNDITY AND GONADOSOMATIC INDEX (GSI) OF *H. MEDIUS*

Figure 3 shows the relationship between GSI and absolute fecundity (Fig. 3a), relative fecundity F_L (Fig. 3b) and relative fecundity F_W (Fig. 3c), respectively. The power function $F = 28557GSI^{0.8218}$ (R = 0.4851, P < 0.01) represents the relationship between absolute fecundity (F) and GSI, power function $F_L = 1354.1GSI^{0.7836}$ (R = 0.5009, P < 0.01) represents the relationship between relative fecundity (F_L) and GSI, and power function $F_W = 162.8GSI^{0.6389}$ (R = 0.3455, P < 0.05) represents the relationship between relative fecundity (F_W) and GSI.

RELATIONSHIP BETWEEN FECUNDITY AND FULTON'S CONDITION FACTOR (K) OF *H. MEDIUS*

Figure 4a shows a parabolic correlation between absolute fecundity (F) and Fulton's condition factor (K) in *H. medius*. The equation was $F=785.13K^2+1504.20K+549.51$ (R = 0.7644, P < 0.05). Figure 4b shows that the relationship between the relative fecundity (F_L) and the Fulton's condition factor (K) can be represented by the parabolic correlation $F_L=57.99K^2+19.34K+74.30$(R = 0.7912, P < 0.05).

RELATIONSHIP BETWEEN BODY WEIGHT AND BODY LENGTH OF *H. MEDIUS* IN BEILIU RIVER

Figure 5 shows the relationships between body weight and body length in female and male *H. medius*. The correlation equation between body weight and body length for female *H. medius* was $W_1 = 0.0198{L_1}^{3.0768}$(r = 0.9400, P < 0.01, n = 51), and the Fulton's condition factor of females was K_1 = 1.60 ± 0.24 (n = 51). However, the correlation equation between body weight and body length for male *H. medius* was $W_2 = 0.0103{L_2}^{3.1641}$ (r = 0.9574, P < 0.01, n = 48), and the Fulton's condition factor of males was K_2 = 1.60 ± 0.25 (n=48).

DISCUSSION

INDIVIDUAL FECUNDITY OF *H. MEDIUS* IN BEILIU RIVER

The ability of a female fish to produce offspring is crucial in determining the reproductive capacity of a population.

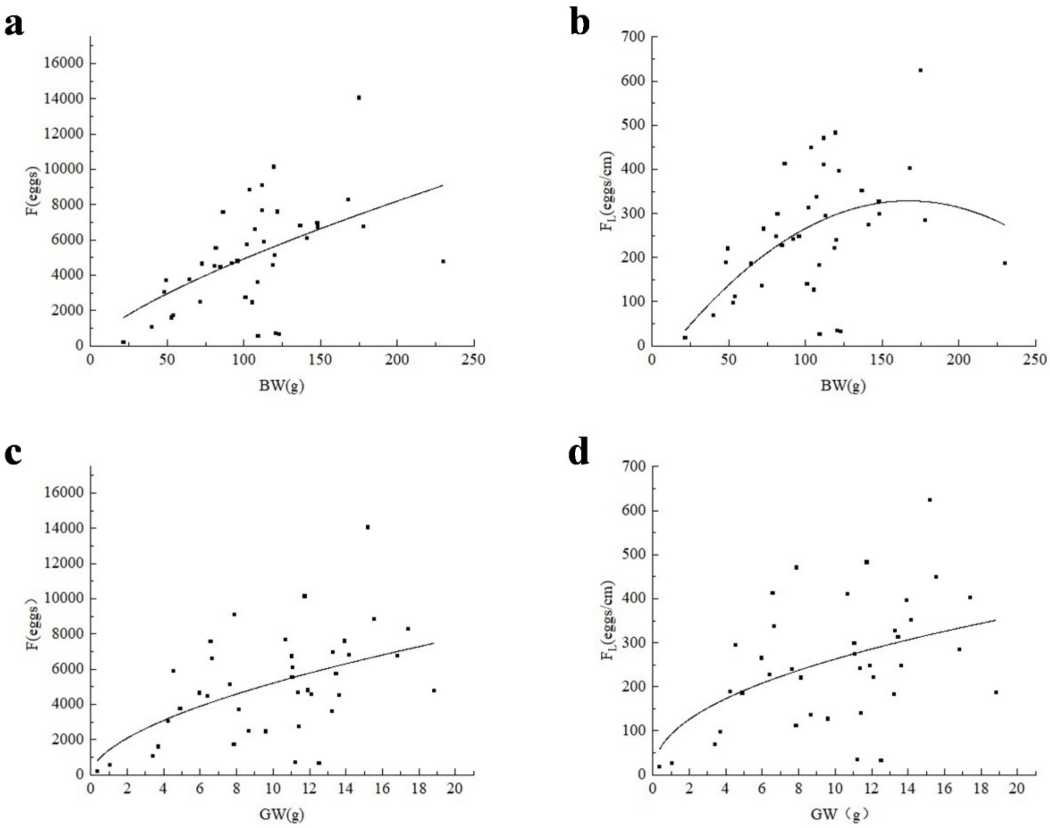

Figure 2. The relationship between fecundity and empty shell weight, gonadal weight of *H. medius*: (a) relationship between absolute fecundity (F) and empty shell weight (BW), (b) relationship between relative fecundity (F_L) and empty shell weight (BW), (c) relationship between absolute fecundity (F) and gonadal weight (GW), (d) relationship between relative fecundity (F_L) and gonadal weight (GW).

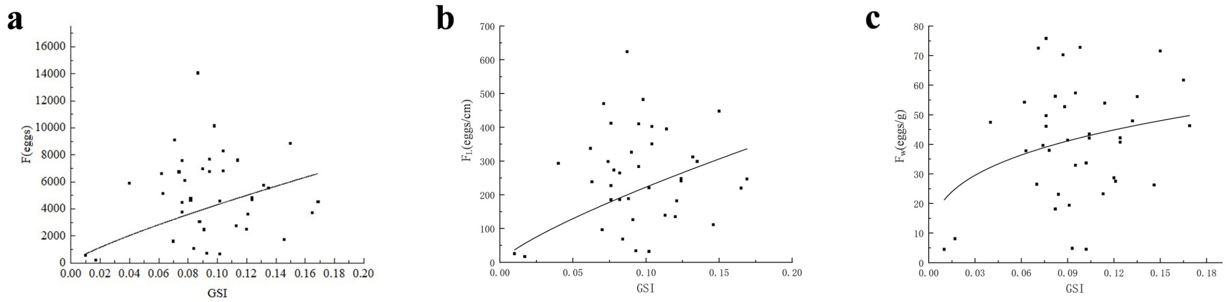

Figure 3. The relationship between fecundity and gonadosomatic index (GSI) of *H. medius*: (a) relationship between absolute fecundity (F) and GSI, (b) relationship between relative fecundity (F_L) and GSI, (c) relationship between relative fecundity (F_W) and GSI.

Studying the individual fecundity of fish not only aids in comprehending the population dynamics of fish but is also significant in understanding fish ecology and fisheries production practices.[8] The fecundity of fish varies depending on their species or population. When compared with other species of fish, such as *Baltic herring*, *Thynnichthys thynnoides*[9] and *Hemiculter leucisculus*,[10] it was found that the fecundity of all of these species was greater than that of individuals of *H. medius* in Beiliu River. In addition, individuals of *H. medius* in the Beiliu River had smaller fecundity than those in Beijiang River.[4] Thus, we hypothesize that *H. medius* in Beiliu River does not use a high egg production reproductive strategy to combat environmental pressures and ensure species continuation. Fish individual fecundity was correlated with biological indicators, generally with age, gonadal weight, empty shell weight and GSI, especially with body length and body weight. There is a diverse expression of individual absolute fecundity in different fish species, and its correlation with body length and body weight varies. For example, the best fitting equa-

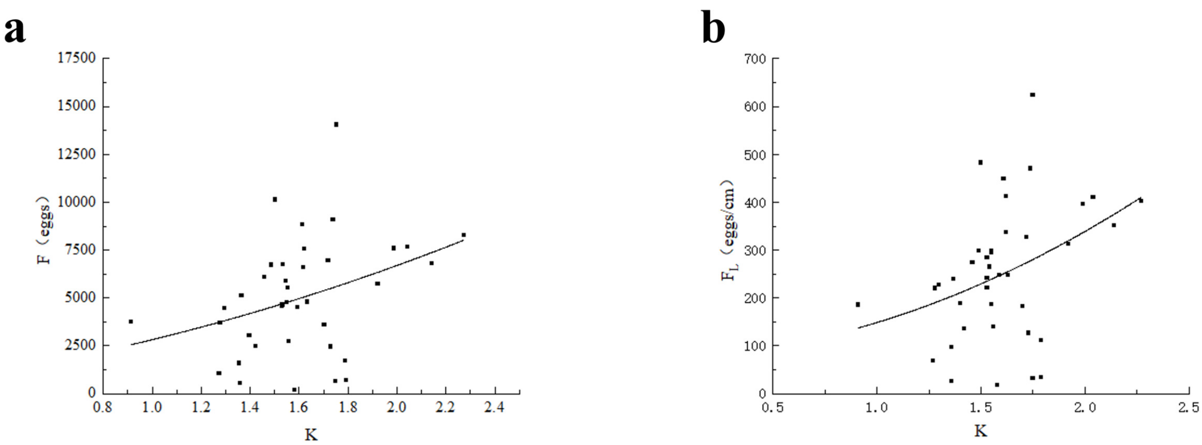

Figure 4. The relationship between fecundity and Fulton's condition factor (K) of *H. medius*: (a) relationship between absolute fecundity (F) and K, (b) relationship between relative fecundity (F_L) and K.

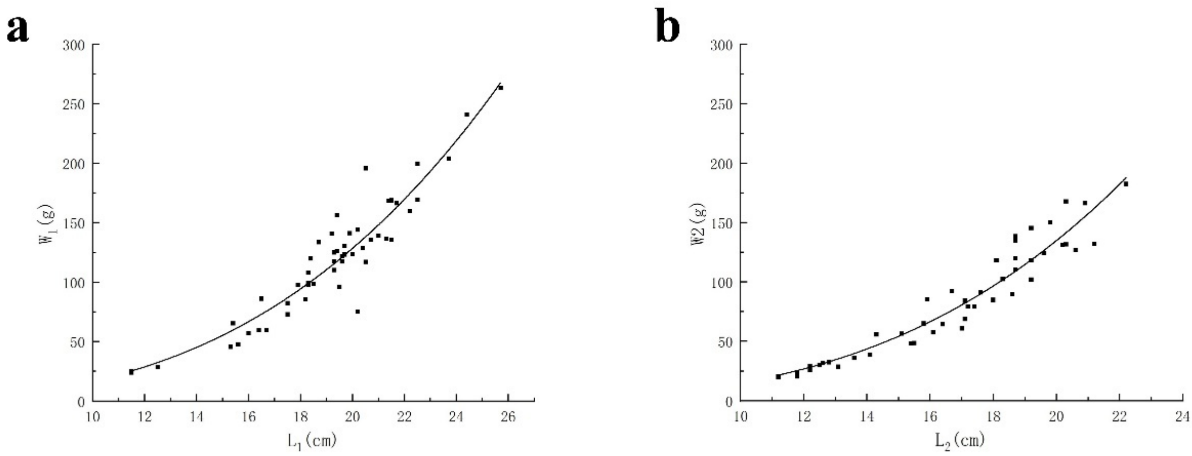

Figure 5. Relationship between body weight (W) and body length (L) of *H. medius*: (a) female population, (b) male population.

tions between absolute fecundity and body length and body weight in Chum salmon *(Oncorhynchus keta*) are quadratic functions,[11] while in Dwarf suckermouth (*Otocinclus vittatus*),[12] there was a positive correlation between absolute fecundity and body length, and body weight. California Sheephead (*Semicossyphus pulcher*),[13] on the other hand, shows a power function relationship between absolute fecundity and body length and body weight, whereas *Neosalanx reganius*[14] have a power function relationship with body length and a linear relationship with body weight. In this research, absolute fecundity and length-relative fecundity of the *H. medius* in Beiliu River were power functions of body length and body weight, while weight-relative fecundity was not significantly correlated with body length and body weight.

RELATIONSHIP BETWEEN BODY LENGTH AND BODY WEIGHT OF *H. MEDIUS* IN BEILIU RIVER

The correlation between the body weight and body length of fish is a crucial factor frequently examined in fish reproduction biology, and it is a widely used formula in fisheries ecology studies.[15] In an ecosystem, obtaining the fish body length-weight relationship equation is crucial for fish conservation and management.[16] Fish fecundity and body length-weight relationships closely reflect the physiological and nutritional status of fish.[17] These characteristics are often used to compare the growth status of fish in different aquatic environments,[18] and estimate growth rates, age structure, condition indices, standing stock biomass and other aspects of fish population [19]. Therefore, body length and weight relationships are essential for comprehensive fisheries studies such as fish biology, physiology, ecology and fisheries assessment and management. The relationship between fish's body weight and its body length is expressed by the formula $W = aL^b$. The value of b is influenced by the environment in which the fish grows and the productivity of the bait organisms. High-productivity environments tend to promote positive anisotropic growth in fish ($b > 3$), while low-productivity areas, like deep-water areas, tend to promote negative anisotropic growth ($b < 3$).[20] For example, the growth coefficient of *Otolithoides pama* (b = 3.018 for males, b = 3.052 for females) was calculated to be greater than 3, indicating that the fish followed a positive anisotropic growth pattern.[7] Islam et al.[14] reported the growth coefficient of *Neosalanx reganius* as b = 3.56, $r^2 = 0.87$, which also indicates positive anisotropic growth of the species.[14] In the present study, the growth coefficient b value was 3.0768 for females and 3.1641 for males of *H. medius* in Beiliu River, indicating positive anisotropic growth of *H. medius*.

The Fulton's condition factor (K) of fish is the ratio of fish body weight to fish body length cubed, which is another expression of the relationship between fish body length and body weight, and it reflects the degree of fish fullness and status of fish survival and growth.[15] Frequently, the Fulton's condition factor can vary between fish species. For example, *Protosalanx hyalocranius* has a Fulton's condition factor of K = 0.49 ± 0.01[21] while *Hemibarbus maculatus bleeker* has a Fulton's condition factor of K = 1.57 ± 0.07.[22] In addition, the Fulton's condition factor of the same fish species also varies by sex.[23] In this study, the Fulton's condition factor of female *H. medius* in Beiliu River was $K_1 = 1.60 \pm 0.24$, and of male *H. medius* was $K_2 = 1.60 \pm 0.25$, and there was no significant difference in Fulton's condition factor between males and females.

COMPARISON OF *H. MEDIUS* BIOLOGICAL INDICATORS IN BEILIU RIVER AND BEIJIANG RIVER

Individual fecundity is closely related to environmental factors, which can greatly influence reproductive biology indicators such as individual fecundity. Depending on the differences in habitat conditions such as feeding, water quality and fishing, various populations of the same species often change their fecundity to adapt to the ever-changing external survival environment.[24] There are differences in the reproductive biology indexes of the same fish species in different water environments.[25] Altogether seven age groups were identified in this study, and the predominant age groups were 1^+ age, 2 age and 2^+ age, with a very low proportion of older fish. In comparison with the dominant age groups in the Beijiang River Basin, the age structure of the *H. medius* population of Beiliu River was simpler and younger. It indicates that the resources of the *H. medius* population were restricted, which may be related to the reservoir area created in the Beiliu River terrace power station,[26] and the relatively large number of younger age groups of *H. medius* due to the greater harvesting pressure.[24] As can be seen from Table 3, the body length, body weight, and individual fecundity of *H. medius* in Beiliu River were smaller when compared to that of *H. medius* in Beijiang River. Reasons for the differences are summarized as follows: Firstly, it could be found after the survey that the Beijiang River Basin had higher yearly average air temperatures, higher yearly average water temperatures, richer in nutrients, and higher stability of habitats. The differences in those habitats may be the reason for the inconsistency in growth conditions and fecundity.[27] Subsequently, the loss and fragmentation of suitable habitat areas for fish due to the construction of the Beiliu River terraced hydroelectric power station resulted in the reduction of genetic diversity and growth performance of the *H. medius* population [28]. Moreover, the survival environmental conditions, food availability and hydrological connectivity of the *H. medius* population in Beiliu River were poor, which forced the *H. medius* population to reach maturity and reproduction stage earlier to adapt to the food shortage and environmental conditions.[26,29] Finally, the seasonal fishing ban period in the Pearl River Basin could not change the problem of *H. medius* population resource exhaustion caused by overfishing [30].

In summary, it is possible that the reasons for the population miniaturization and lower individual fecundity of *H. medius* in Beiliu River are related to climate, increasing difficulty in obtaining food for bait, differences in hydrological conditions, habitat fragmentation, and overfishing.[31] Further research is needed to confirm these speculations.

CONSERVATION OF THE BREEDING POPULATION OF *H. MEDIUS*

H. medius prefers to live in clear, fast-flowing water and requires a flowing environment for spawning. Therefore, it is highly susceptible to water pollution and hydrological changes.

In recent years, the Beiliu River has suffered serious damage to flowing water habitats due to human activities such as the construction of water conservancy facilities and sewage discharge, as well as the invasion of exotic species, resulting in a decreasing range of activities and habitat fragmentation and overall decline in population genetic diversity for *H. medius*.[32] As an economically important fish in the Beiliu River, *H. medius* resources have been severely damaged by overfishing.[3] The results of this study show that the average length, weight, and individual fecundity of *H. medius* in the Beiliu River are smaller than those in other habitats, and the proportion of the lower age groups is higher. In addition, we know from the inquiry and investigation that the artificial propagation of local *H. medius* has not yet been carried out, which has caused the resources of *H. medius* in the Beiliu River to show a declining and miniaturizing trend. Therefore, conservation of the natural resources of *H. medius* and its artificial breeding are now urgently needed.

The population of *H. medius* naturally reproduces in seven different age groups ranging from 0^+ to 6^+ age. However, this study only collected data from the reproducing population of 1~3 age. The reason for this may be related to habitat destruction, overfishing, and other factors that are making it difficult for *H. medius* to survive in the Beiliu River.[32] As a result, the reproductive population resources of *H. medius* are decreasing. The study shows that the reproductive population is mainly concentrated in 1^+ age, 2 age, and 2^+ age. These three age groups contribute to

Table 3. Comparison of *H. medius* biological indicators in Beiliu River and Beijiang River.

Index	Beiliu River *H.medius*		Beijiang River *H.medius*	
	♀	♂	♀	♂
Minimum mature body length（cm）	15.3	12.6	13.0	12.9
Minimum mature body weight（g）	45.62	31.85	45.36	44.47
Age of first sexual maturity（age）	1^+	0^+	1^+	1^+
Absolute fecundity（eggs）	5020		15962	
Relative fecundity of body weight（eggs/g）	41		96	
Relative fecundity of body length（eggs/cm）	253		762	
Reproductive colony sex ratio（♀：♂）	1.06:1		1.27:1	
body length（cm）	18.01	16.70	18.86	17.29
body weight（g）	106.83	83.47	150.38	105.98

89.47% of the total reproductive contribution. If the resources of the population at these ages decrease sharply, it will have a significant impact on the continuation of the whole population.

Therefore, in order to ensure the sustainable development of this species, certain conservation measures need to be developed in response to the current resource status of *H. medius* in the Beiliu River. Firstly, the protection of the 1^+ age, 2 age, and 2^+ age groups of groups with high contribution to the fecundity of the population should be strengthened to reduce their fishing volume, and the age of the fishing group should not be less than age 3. Secondly, set up a closed season and a closed area during the February-March breeding period of the *H. medius*, and establish a nature reserve if necessary to ensure the normal survival and reproduction of the *H. medius* population. Then, strengthen fishery management and strictly prohibit fishing activities during the closed season. At the same time, actively carry out the artificial breeding of *H. medius* and increase the release efforts. Finally, to promote the restoration of the *H. medius* resource stock, resource surveys should be carried out in a planned manner, and more in-depth research should be conducted on the reproductive biology and population dynamics of the *H. medius*. This will furnish invaluable theoretical insights to guide activities such as artificial breeding, seedling incubation, and the enhancement and release of stock.

AUTHORS' CONTRIBUTION

Conceptualization: Lilong Chen (Lead). Data curation: Lilong Chen (Lead). Investigation: Lilong Chen (Equal), Yusen Li (Equal), Yangyan Sun (Equal), Jiayang He (Equal), Zhe Li (Equal). Methodology: Lilong Chen (Lead). Resources: Lilong Chen (Equal), Yusen Li (Equal), Yangyan Sun (Equal), Jiayang He (Equal). Software: Lilong Chen (Equal), Yangyan Sun (Equal). Visualization: Lilong Chen (Equal), Yusen Li (Equal), Yangyan Sun (Equal), Jiayang He (Equal), Zhe Li (Equal). Writing – original draft: Lilong Chen (Lead). Writing – review & editing: Lilong Chen (Equal), Hangyu Lin (Equal), Shengqi Su (Equal). Validation: Hangyu Lin (Equal), Shengqi Su (Equal). Funding acquisition: Yong Lin (Equal), Shengqi Su (Equal). Supervision: Yong Lin (Equal), Shengqi Su (Equal). Project administration: Shengqi Su (Lead).

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