

Study on the Growth and Age of *Spinibarbus denticulatus denticulatus* in Pearl River System

Guangjun Wang, Deguang Yu, Jun Xie, Haiying Wang, Ermeng Yu, Wangbao Gong & Lihua Tang
Pearl River Fishery Research Institute, Chinese Academic of Fishery Science
Guangzhou 510380, China
Tel: 86-20-8161-6178 E-mail: wgj5810@163.com

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Abstract

Study on the growth characteristics of *Spinibarbus denticulatus denticulatus* Oshima were carried out based on the specimens collected from Xijiang valley and Beijiang valley of the Pearl River system. The results show that the annual-ring feature belongs to the loose-close and cut pattern. The new annual-ring is formed during the period from April to June. The relationship between body length and weight of *S. d. denticulatus* in Xijiang valley and Beijiang valley can be expressed by the power function equations: $W_x=2.4984 \times 10^{-2} L^{2.9996}$ ($r=0.9561$) and $W_B=1.3733 \times 10^{-2} L^{2.8159}$ ($r=0.9253$) respectively. Based on the analysis of the growth stage, the female *S. d. denticulatus* gets mature at the age of five years old. The male one gets mature at the age of three years old. The breeding season of *S. d. denticulatus* is from April to June.

Keywords: *Spinibarbus denticulatus denticulatus*, Age, Growth

1. Introduction

Spinibarbus denticulatus denticulatus Oshima, also being called bamboo caldwelli or bamboo carp, is a kind of common commercial fish in the Pearl River system (Wu, 1977; Zhu, 1989; Yang & Chen, 1995; Dan, 2000). It has become the main species cultured in rivers, reservoirs and ponds for its rapid growth, big size, exquisite meat and fresh flavor. In nature, *S. d. denticulatus* mainly distributes in Xijiang valley and Beijiang valley, which locate at the upreach and midreach of the Pearl River system (Zhang, 1998; Luo & Xie, 2004; Tang, 2004; Zeng, etc, 2004). Generally speaking, the body weight of *S. d. denticulatus* is 1.0-1.5 kg, with bigger individual reaches to 5-8 kg (Pearl River Fisheries Research Institute, 1991). Studies on *S. d. denticulatus* are reported as follows: Jiang Linyuan etc. had reported the relationship between age and growth under cultured condition (Jiang, etc, 2003); Yi Zusheng etc. had studied the embryonic development of *Spinibarbus denticulatus denticulatus* (Yi, etc, 2004). Xie Gang etc. had studied the relationship between embryonic development and water temperature, and salinity (Xie, etc, 2003). However, there was no systematic study on population biology under natural conditions. So in this paper, the age, growth and breeding of *S. d. denticulatus* in the Pearl River water system had been studied, which would provide scientific foundation on further development and protection of this fish resource.

2. Materials and Methods

2.1 Materials

S. d. denticulatus specimens were collected from Xijiang valley (From GuiPing of GuangXi to SanShui of GuangDong) and Beijiang valley (From Heyuan of Guangdong to SanShui of Guangdong) of the Pearl River water system between March in 2002 and December in 2004. 430 samples were captured with triple trammel nets. Scales were collected randomly from 200 samples and stored in numbering bags for age identification. 100 female and 30 male gonad samples were collected and immersed in 10% formalin for further analysis.

2.2 Methods

Age identification: The lateral line scales were observed under dissection microscope to identify age. After amplifying 20 times by projector, the scale length (R) and the radius of each annual rings ($R_1, R_2, R_3 \dots R_n$) was measured. Scale length was measured from the focus to the right angle of front zone of the scale. The radius of annual rings was measured from the focus to the interface of the front zone and the lateral zone.

Gonad histological observation: Gonads tissue was fixed in formalin, embedded in paraffin and stained by hematoxylin-eosin (HE) for pathological observation.

The radiuses of eggs: measured under microscope by eyepiece micrometer.

Growth index = $(\log L_2 - \log L_1) \times L_1 / 0.4343(t_2 - t_1)$, (L_1 and L_2 are body lengths at two adjacent time t_1 and t_2);

Growth rate of scale edge (α) = $(R - R_n) / (R_n - R_{n-1}) \times 100$, (R_n and R_{n-1} are the radii of the last annual rings and penultimate annual rings).

3. Results

3.1 Age Identification

Morphological characteristics of scales: The scale of *S. d. denticulatus* was hexagonal, middle to big cycloid. The entire scale could be divided into front zone, back zone and lateral zone. Anterior parazona was wider than hinder parazona, but hinder parazona was longer than anterior parazona, which accounted for 2/3 of the scale radii. Radiating furrow was not vertical with scale edge. Ring tablets were concentric circles and gradually form growth bands annually. Ring pattern in postzone scale turned to irregular granular protuberances.

Characteristics of annual rings: The growth of fish was affected by environment which change rhythmically, these phenomena reflected in scales, otoliths and other hard tissue. Fish grew faster in summer, so scales formed loose broad-bands. While fish grew slower in winter, the scales formed dense narrow-bands. The broad-bands and narrow-bands formed annual rings. The annual rings of *S. d. denticulatus* belongs to the loose-close and cut pattern. Generally speaking, ring tablets showed as loose-close structure before sexual maturity and sometimes the accretion of parazona and ring tablets were natural continuation of ring tablets from previous year. The difference was that newborn part dispersed toward the edge sparsely. However, annual rings showed as cut structure after sexual maturity and ring tablets often became disorder. Loose-close and cut structure appeared at the same annual ring. In the cut area, the inner edge showed as dense ring and the outer edge showed as loose ring. These phenomena occurred obviously in the postzone - parazona interface.

The subaltern ring occurred non-periodically and incompletely. They only appeared in partial prozone and lateral zone of scales and they were not commonly seen in elderly fish (over 5 years). Not all scales had subaltern ring in the same fish, so it was easy to distinguish.

3.2 Population Composition

Age composition: In Xijiang valley, *S. d. denticulatus* was mainly at the age of 0-2, which occupied 73.67% of the 376 samples, while fish at the age of 3-5, 6-10 years respectively occupied 19.14% and 6.64%, and fish of over 11 years occupied only 0.53%.

Body length composition: The body lengths of 376 specimens were statistically classified. Most of the body lengths were between 11.5cm and 29.5cm, which accounted for 63.30%. Body length between 29.5cm and 38.5cm accounted for 13.83%. The body length of the biggest male and female was 59.5cm and 69cm, and the weight was 5250g and 8250g, respectively.

In Beijiang valley, *S. d. denticulatus* were mainly at the age of 0-3, which accounted for 66.67% of the 54 samples. Among which, the fish at the age of 2 were the majority, which accounted for 25.93% of the total.

3.3 The Annual Ring Forming Period

The growth rate of scale edge $\alpha = (R - R_n) / (R_n - R_{n-1}) \times 100$ in Hass's method was used to calculate the change of average value of α in every age group (Hass & Reckslek, 1995). When the new annual ring was forming, the average value of α was small. When the average value of α was increasing, it meant the new annual ring was going to form (Zhang, etc, 1981). According to annual change of α of *S. d. denticulatus* in Xijiang valley, the annual ring formed only once in a year, and new annual ring appeared mainly from April to June. This was proved by the captured *S. d. denticulatus* specimens during April to May, which just formed new annual ring. Growth rate of scale edge was inconsistent through a year. From December to next March, α value was relatively stable, that is to say the scale grew slowly in winter and spring. From July to November, α value increased gradually, which means scale edge grows rapidly in summer and autumn. The annual change of scale growth reflected the seasonal growth of *S. d. denticulatus* in Xijiang valley to some extent: it grew rapidly in summer and autumn, and slowly in winter and spring (Table 1).

According to gonadal histological study, *S. d. denticulatus* spawn between April and June, which coincided with the annual ring forming period. So, the annual ring of *S. d. denticulatus* formed only once in a year.

3.4 The Relationship Between Body Length and Body Weight of *S. d. denticulatus*

Body length and body weight were two correlated variables of animal growth. The result showed that the relationship between body length and weight of *S. d. denticulatus* in Xijiang and Beijiang valley was power

functional and could be expressed with the formula of $W=aL^b$ (Figs. 1 and 2). According to the body length and weight value of all 430 specimens, formulas were got by Linear Regression method: $W_X=2.4984\times 10^{-2}L^{2.9996}$ ($r=0.9561$, $p<0.01$) for Xijiang valley and $W_B=1.3733\times 10^{-2}L^{2.8159}$ ($r=0.9253$, $p<0.01$) for Beijiang valley.

3.5 Growth Stage Analysis

From each age group including male and female in Xijiang and Beijiang valley, body length increased most rapidly in the first year and then the second year. With age increasing, annual growth rate of body length tended declining. On the contrary, body weight gain was the smallest in the first year, in the second year it began to increase. Annual growth rate of weight increased gradually with age increasing, but different age had different increasing amount. The 4-5 age groups had the largest increasing amount. Male and female *S. d. denticulatus* had no difference in growth when they were at the age of one to five years old, but over five years, female *S. d. denticulatus* had larger increasing amount in body length and weight than male one (Table 2).

Relative growth rates and growth index were used to divide growth stage, which could express growth features objectively. According to the study on gonadal histology, the female *S. d. denticulatus* in Xijiang valley got matured at the age of five years old. The *S. d. denticulatus* younger than five or four years was juvenile, whose gonadals was not mature or just primarily matured, they still grown quickly. Relative growth rates and growth index of body length and weight were the largest at that time. At the age of five to ten, the fish became adult and grew stable. Most food consumed for gonadal development and fat accumulation, so relative growth rates and growth index of body length and weight decreased gradually (Table 3).

S. d. denticulatus in Beijiang valley had the most rapid growth at the age of one to three, the relative growth rates and growth index were higher. When they were over four years, they grew slower, and the relative growth rates and growth index decreased.

3.6 Breeding

Beside of visual inspection, histological slices were mainly used to distinguish gonadal development stage (Shanghai Fisheries University, 1979; Su, 1995). Domestic scholars often divided the gonadal development stage into six phases. They were as follows:

Phase I : Ovary was linear, white and transparent. Under histological observation, the oocytes were polygonic and arranged closely. The nucleus occupied most part of the cells. Male or female couldn't be distinguished with naked eyes.

Phase II : The breadth of ovaries increased and back-end were larger, with showing itself light incarnadine. Oocytes enlarged, arranged and ranged closely. Nucleus located at the center of the cells and nucleoli manifolded along the edge. Oocytes in ovary were in small-growth period. The increase of protoplasm led to the small increase of volume of cells. The diameter of oocyte was between 37.50 μ m and 159.84 μ m.

Phase III: Ovary expanded obviously because of the rapid development of oocytes. Cells were cylinder, with bright yellow. The width of ovary was 1.2cm and the length was about 7cm. Eggs could be seen with naked eyes, with diameters between 83.25 μ m and 1731.60 μ m. Oocytes had plenty yolk with nucleus in the center. The number of nucleoli increasing, two layer of follicular membrane and two or three liquid vacuoles appeared.

Phase IV: Ovary developed timidly, with the orange appearance. The eggs were bigger, with the diameter from 1393.00 μ m to 1798.20 μ m. Yolk appeared in oocytes and protoplasm was displaced to the area around nucleus and near inner edge of cell membrane. Vacuoles also were pushed to the edge of cells.

Phase V : Ovarys were orange, tumid and bursiform. Eggs were big and there were free mature ova in ovarys. Matured ova were golden, spherical and transparent. The diameter of ova before absorbing water was between 2875.0 μ m and 3122.0 μ m. The ova were buoyant.

Phase VI: Ovary diminished greatly and its tissues became soft. Surface vessels were filled with blood. Main remainder in ovary was oocyte at phase II and follicular membrane which had discharged ova. Oocyte which had not discharged would be digested and absorbed soon.

The development of the spermary was simultaneous with that of ovary, which also be divided into six phases.

Phase I : Gonad was undeveloped, linear and clung to the celarium. Male or female could not be distinguished with naked eyes. Spermatogonia distributed dispersedly could be seen by histological observation.

Phase II : Testis was linear, semiopaque and vessels was not obvious. The number of spermatogonia increased and arranged bunchly histological observation.

Phase III: Spermary was columnar. There were no sperm extruded when abdomen was pressed. Primary spermatocytes could be seen by histological observation.

Phase IV: Spermary was opalescent and vessels distributed on the surface. Milky sperm could be extruded when abdomen was pressed at late stage. Primary spermatocytes, secondary spermatocytes and sperms could be seen by histological observation.

Phase V: The spermatogenic cysts were full of sperms. Abundant milky sperm could be extruded from cloaca when abdomen was lightly pressed or head was lifted.

Phase VI: Spermary diminished greatly in volume and the gonadal tissues were soft. Main remainder in spermary was some spermatogonia, primary spermatocytes and connective tissues. Testis recurred to phase III and then developed again.

100 ovarys were observed. Among which, 68% were at phase II, and all were over four years' age. 17% were at phase III and IV, and they all were five or over years old. Phase III and IV were the period that yolk began to deposit and accumulate, during which ova tended to mature, which showed that female *S. d. denticulatus* got mature at the age of five. At the same time, 30 testes were observed, there was no testis got mature at the age of no less than three years old. So the male *S. d. denticulatus* got mature should be at the age of three.

4. Conclusion and Discussion

According to the captured specimens of *S. d. denticulatus*, female fish got mature when they were over five years old. According to the report from Jiang Linyuan etc, female *S. d. denticulatus* got mature at the age of 4–5 under culture condition (Jiang, etc, 2003). These phenomena may be caused by the different environment of culture and natural condition. *S. d. denticulatus* cultured artificially are fed with compound feed, the nutrients was abundant, so the gonad developed earlier. In this study, the mature samples may not enough, whether the sexual mature age is accurate or not need further studies. The *S. d. denticulatus* specimens in the study had large age span, this phenomenon reflected their sexual mature age was comparatively late. At the same time, it was showed that the breeding season of *S. d. denticulatus* was from April to June in this study, but Yi Zusheng etc had reported that the breeding season of *S. d. denticulatus* was from June to September under cultured condition. This may be caused by different rearing environment^[11].

0–2 years old *S. d. denticulatus* in Xijiang valley occupied 73.67% of the total specimens, and 0–3 years old *S. d. denticulatus* in Beijiang valley occupied 66.67% of the total specimens, which indicated that juvenile *S. d. denticulatus* were captured excessively in Pearl River system. However, fishing target should be the populations with most of them got mature. Liao Fuchu reported that random enhancement of ships and nets, the use of illegal fishing appliance and illegal fishing during forbidden fishing period were the main reason causes leading to the decline of fisheries resources in Dongting Lake(Liao, etc, 2002). Presently, the number of *S. d. denticulatus* in Pearl River system reduced sharply, the relevant administration departments should promulgate corresponding rules, delimitting the fishing-forbidding areas and periods as soon as possible. Fishing should be restricted especially when fish were in spawning and propagating seasons. Only in this way, the *S. d. denticulatus* fishery resources could be protected and utilized reasonably, and achieved sustainable development.

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Table 1. The marginal increment ratio of scale of *S. d. denticulatus*

Month	1	2	3	4	5	6	7	8	9	10	11	12
Average value of α	6.36	7.38	8.00	4.38	2.30	3.60	7.92	8.79	7.74	8.97	10.18	9.27
Number of spcimens	3	5	7	12	7	4	6	11	11	7	4	22

Table 2. Measure and annual increment of different ages of *S. d. denticulatus*

Sex	Age	Number	Measure body length /cm	Annual increment/cm	Measure body weight/g	Annual increment /g	
Xijiang Valley	♀	1	57	20.47±2.93	20.47	228.46±94.51	228.46
		2	86	27.52±3.36	7.05	541.54±183.82	313.08
		3	15	34.25±3.33	6.73	946.53±272.13	404.99
		4	11	40.02±2.21	5.77	1586.21±268.22	639.68
		5	13	46.76±2.01	6.74	2510.32±412.61	924.11
		6	7	49.98±2.23	3.22	2974.53±404.32	464.21
		7	9	54.32±5.78	4.34	4113.67±1089.22	1139.14
	≥8	3	55.46±10.42	1.14	4422.78±2545.36	309.11	
	♂	1	42	19.90±2.88	19.90	209.09±82.04	209.09
		2	92	27.87±3.29	7.97	547.05±187.23	337.96
		3	14	33.40±3.58	5.53	915.87±288.73	368.82
		4	13	40.60±2.55	7.20	1540.63±364.11	624.76
		5	6	43.43±2.17	2.80	2157.14±356.40	616.51
		6	3	51.50±0.71	8.07	3075.16±106.07	917.86
7		3	52.25±1.55	0.75	3275.26±320.16	200.10	
≥8	2	53.00±6.89	0.75	3900.26±1316.85	625.00		
Beijiang Valley	♀	1	6	20.78±3.12	20.78	245.36±94.69	245.36
		2	9	28.45±2.96	7.67	522.36±211.45	277.00
		3	8	32.96±1.65	4.51	934.67±270.50	412.31
		4	4	40.23±3.58	7.27	1611.24±188.59	676.57
		5	3	44.98±3.36	4.75	2456.95±236.19	845.61
		6	3	50.76±3.36	5.78	2869.34±546.29	412.39
		7	2	53.96±4.63	3.20	4054.63±1523.63	1185.29
	≥8	2	54.87±7.22	0.91	4411.03±653.45	356.40	
	♂	1	4	19.87±3.21	19.87	212.46±78.46	212.46
		2	5	26.55±3.12	6.68	521.25±214.46	308.79
		3	4	32.98±5.63	6.43	877.68±301.27	356.43
		4	2	37.65±3.39	4.67	1312.49±386.41	434.81
		5	1	45.45	7.8	2284.17	971.68
		6		-		-	
7		1	52.31		3533.21		
≥8		-		-			

“-”No fish specimen collected.

Table 3. Analysis of growth stage of *S. d. denticulatus*

Age	Xijiang valley			Beijiang valley		
	Growth index	Body length gain/%	Body weight gain/%	Growth index	Body length gain/%	Body weight gain/%
1 ⁺						
2 ⁺	6.18	35.62	140.42	6.09	34.52	132.44
3 ⁺	5.56	22.38	74.22	5.82	23.45	75.14
4 ⁺	6.00	19.50	69.80	5.26	16.68	69.85
5 ⁺	5.06	13.41	51.94	6.49	17.71	58.23
6 ⁺	4.52	10.40	25.29	3.78	7.83	34.58
7 ⁺	2.40	4.88	17.58	3.21	7.09	18.33
8 ⁺	1.85	3.56	11.79	1.21	2.27	7.92

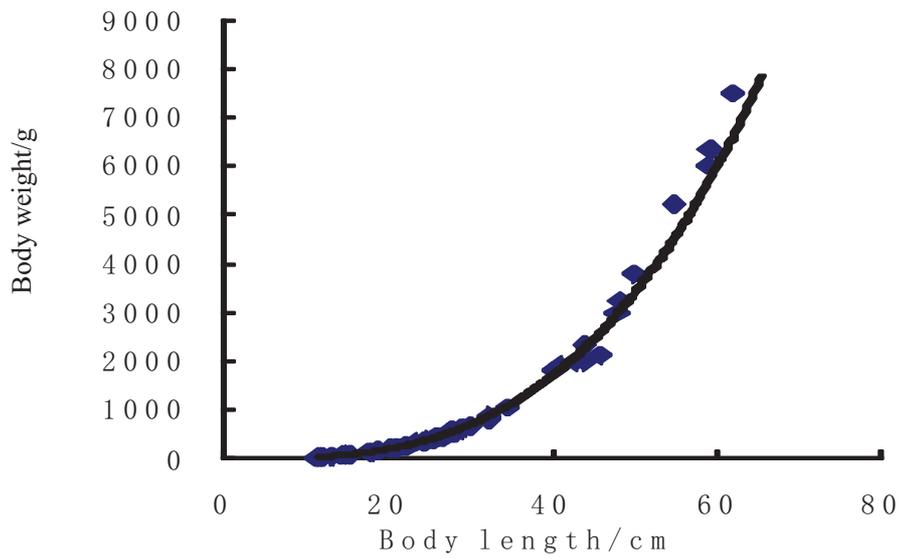


Figure 1. The relationship between body length and weight of *S. d. denticulatus* in Xijiang valley

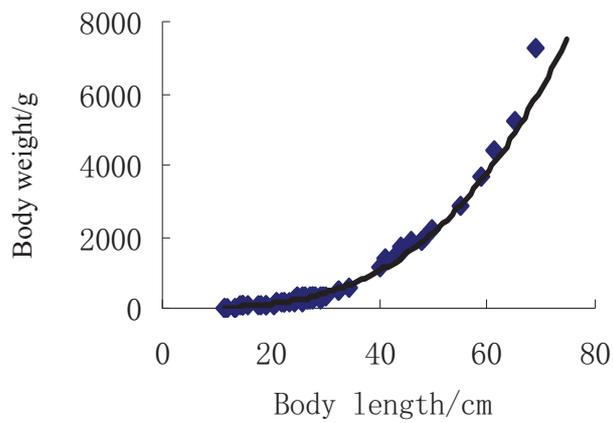


Figure 2. The relationship between body length and weight of *S. d. denticulatus* in Beijiang valley