J Indian Inst Sci. 65(C), June 1984, pp. 41-51

Studies on the maturation and spawning of *Schizothorax curvifrons* Heckel from River Jhelum, Kashmir

SHYAM SUNDER *
Centre of Research for Development, University of Kashmir, Srinagar, Jammu and Kashmir, India.

Abstract

Schizothorax curvifrons spawns once a year during a restricted period, as indicated by the studies on ova diameter, gonadosomatic index, maturity cycle and the actual spawning of the fish in nature. About 50% of the female specimens were found to be mature at 250 mm length during spawning season. Gonadosomatic and gastrosomatic indices bear an inverse relationship to each other. Males and females did not reveal any significant departure from the 1:1 sex ratio.

Key words: Ova diameter, maturity stages, gonadosomatic index, gastrosomatic index, *Schizothorax curvifrons*.

1. Introduction

Schizothorax curvifrons, an indigenous carp, supports an important commercial food fishery (about 18.60%) among the subfamily Schizothoracinae, from River Jhelum flowing through the heart of Srinagar city. Since no information on the biology of breeding of the species is available from this ecosystem, an attempt has been made to investigate the same. Information on the breeding of other *Schizothorax* sp. from Kashmir valley has been reported by earlier workers[1-5].

2. Material and methods

343 specimens of *S. curvifrons* in the total length range of 83-411 mm and weight range of 7-736 g were procured from the Zerobridge and the Chhatabal fish assembly centres during July 1980-June 1982. The ovaries were preserved in 5% formalin for detailed observations.

The diameter of 200 ova was measured at random from each ovary under a microscope using an ocular micrometer to study the progression of ova and assign maturity stages. In order to elucidate the spawning season, 25 large sized ova from each of the ovaries of fish were measured and the mean ova diameter for each month was determined. Gonadosomatic index was calculated by the formula: weight of gonad x 100 / weight of fish. Gastrosomatic index, on the other hand, was calculated by multiplying the weight of gut by 100 and then dividing the product by the weight of the fish.

* Present address: Srinagar Research Centre of the CIFRI, Harwan 191 123, Srinagar, Kashmir.

3. Observations

3.1 Female reproductive organs

The ovaries in *S. curvifrons* are of the cystovarian type. The two lobes were found to be symmetrical. However, in a few specimens, the left lobe was slightly longer than its counterpart.

3.2 Distribution of ova in the ovary

In order to study the distribution of ova in the different regions of the same ovary, three cross-sections were taken from anterior, middle and posterior regions of a lobe of a mature ovary. Each section was further sub-divided into three sub-sections which were subjected to ova diameter measurements (Table I). The results of variance indicated that the difference between subsections was insignificant, thereby indicating that the ova were uniformly distributed in the ovary.

Table 1
Frequency distribution of ova diameters from various parts of an ovary of *S. curvifrons*

Ova diameter (mm)	Anterior			Middle			Posterior		
	A_1	A_2	A_3	M_1	M_2	M_3	P_1	P_2	P_3
0.8	2	—	5	—	3	—	—	1	—
0.9	1	5	7	—	—	—	1	3	6
1.0	2	7	0	6	4	1	4	1	9
1.1	7	3	8	10	7	6	—	7	4
1.2	9	3	12	14	6	9	13	9	3
1.3	11	13	9	8	10	9	12	5	8
1.4	8	10	16	22	16	20	17	8	12
1.5	17	9	10	17	12	27	15	15	9
1.6	28	26	21	16	19	15	21	14	26
1.7	16	12	18	12	21	19	20	26	31
1.8	—	8	3	4	13	—	8	1	5
1.9	2	1	—	3	—	—	—	3	3
2.0	—	1	—	—	—	—	—	2	1
Total	103	98	109	112	111	106	111	95	117

Analysis of variance of ova diameters from various parts of the ovary (F-test).

Source of variation	Degree of freedom (D.F)	Sum of squares (S.S.)	Mean square (M.S.)	F
Between sections	8	29.85	3.73	—
Within sections	108	6252.92	57.90	0.064
Total	116	6282.77	—	—

Inference: Non-significant.

3.3 Distribution of ova in right and left ovaries

The possible difference between the frequency distribution of ova in the right and left lobes of the paired ovaries was examined (Table II). Results based on two specimens exhibited non-significance between the two lobes of ovaries. Having found this, the subsequent monthly samples were taken only from the middle region of the ovary.

3.4 Seasonal changes in gonadial condition

On the basis of seasonal changes in the morphology, the ovaries of *S. curvifrons* were classified into seven stages of maturity, closely corresponding to the international scale[6] (Table III). Microscopically also, the ovaries were classified arbitrarily into seven stages of maturity by plotting ova diameter frequency polygons and grouping the data from each fish according to the location of largest mode in diameter distribution of ova. Figure 1 illustrates the course traversed by ova from immature stage to maturity.

3.5 Size frequency distribution of ova during various months

In the average ova diameter frequency polygons of *S. curvifrons* (fig. 2) during July, there was mode 'a' at 0.2 mm (35.61% of the total ova) with a small mode 'b' at 0.7 mm. The latter progressed during subsequent months and got separated from mode 'a', being the general immature egg stock which was more or less present in almost all the months and therefore

Table II

Ova diameter frequencies of right and left ovaries of some specimens of *S. curvifrons* with test for significance

Ova diameter in mm	March 1981 Total length = 281 mm		March 1982 Total length = 266 mm	
	Right	Left	Right	Left
0.8	—	—	—	4
0.9	8	—	24	11
1.0	15	9	13	7
1.1	11	18	8	20
1.2	4	12	16	21
1.3	17	12	25	11
1.4	16	13	21	28
1.5	24	19	41	32
1.6	16	15	26	31
1.7	22	35	26	13
1.8	40	52	22	17
1.9	20	23	14	12
2.0	9	16	8	8
2.1	—	6	—	3
2.2	4	6	4	—
2.3	1	—	—	—
Total	207	236	248	218
Chi-Square	1.89		1.93	
Inference	Non-significant		Non-significant	

Table III
Stages in ovarian development of *S. curvifrons*

Stage (International scale)	Degree of maturity	Range in diameter of most mature groups (mm)	Model diameter ova (mm)	No. of specimens examined	Appearance under microscope	Peak months of availability
I	Immature	0.1-0.3	0.2	17	Ova transparent, invisible to the naked eye. Nucleus visible under microscope Blood vessels inconspicuous.	July-August
II	Maturing	0.3-0.9	0.7	34	Ova transluscent but granular. Yolk formation starts. Nucleus becomes invisible as yolk formation continues.	August-September
III	Maturing	0.1-1.4	1.3	36	Ova medium sized, opaque. Yolk formation in progress. Visible to naked eye. Distinct blood capillaries.	November-December
IV	Mature	1.4-1.6	1.5	18	Ova large, richly laden with yolk, yellow coloured.	January
V	Mature	1.6-1.9	1.7	31	Ova large, fully yolked mostly free from follicles.	February
VI	Ripe	1.9-2.2	2.0	17	Ova large, glistening, free from each other. With slight pressure on abdomen eggs extrude out.	May
VII	Spent	Ova in various stages of development.		13	Small, shrunken, blood shot, flaccid ovary. Degenerating with high degree of vascularity.	June-July

not taken into account presently. Progression of mode 'b' was fast during post-spawning months from July-November, when it shifted from 0.7-1.3 mm. Thereafter, the shifting of mode was slow (1.4-1.8 mm) during winter months and early spring (December-March). With the approach of favourable environmental conditions (increase in temperature and photoperiod), the ova progressed to modes at 1.9 and 2.0 mm during April and May respectively. In June, in addition to the mode 'b' at 2.0 mm (with maximum ova diameter of 2.4 mm), again the appearance of mode 'a' was observed at 0.2 mm, representing maturing virgin/recovering spent stages. Thus, the mature and ripe ova in *S. curvifrons* formed only one mode ('b') sharply differentiated from the general immature stock (mode 'a').

3.6 Male reproductive organs

The testes of *S. curvifrons,* when mature, are paired elongated, soft-textured bodies and are whitish in colour. On the basis of size, colour and shape, they were also classified into seven stages of maturity.

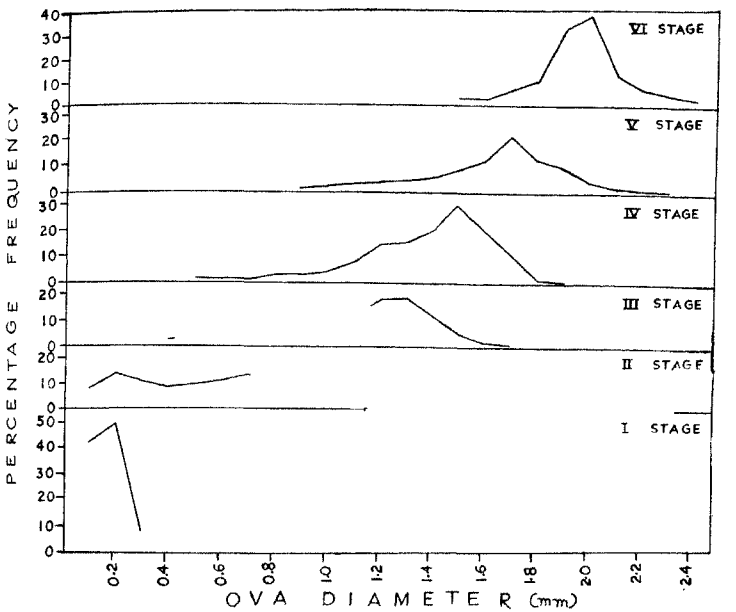

FIG. 1. Ova diameter frequency polygons showing the growth of immature ova towards maturity in *S. curvifrons*.

3.7 Growth rate of gonads

The relationship of gonads to the size of fish at mature stage was established in *S. curvifrons* by the method of least squares and the mathematical values arrived at were as follows:

Females: $Y = 2.8043 + 0.3582\ X$ ($r = 0.9860$)
Males : $Y = -1.1040 + 0.3476\ X$ ($r = 0.9946$)

where X = total length of fish in mm and Y = length of gonad in mm.

3.8 Size at first maturity

The data pertaining to mature females were tabulated in 10 mm class intervals and the percentage occurrence of mature females (IV maturing stage onwards) to the total number of fishes was examined. No female less than 190 mm in total length was mature. About 40% fish were mature at 210 mm, 50% at 250 mm and at 310 mm all the fish were observed to be mature.

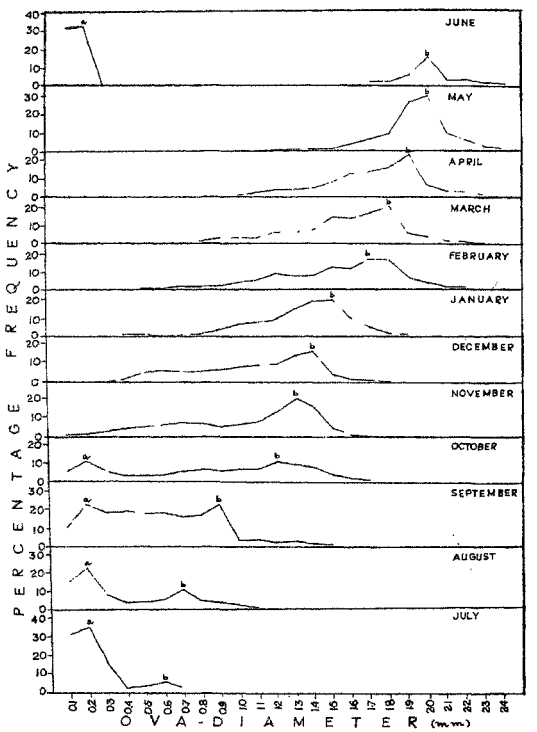

FIG. 2. Month-wise size frequency of ova in *S. curvifrons*.

3.9 Spawning season

The spawning season of *S. curvifrons* lasted from May to July with a peak in June. This was confirmed through the following parameters:

(i) *Stages of maturity:* In the case of females, the majority of specimens were immature, mostly in I and II stages of maturity, during June-November with their maximum occurrence (100%) in August (Table IV). From September onwards, the maturing specimens (Stage III) began to appear with the peak (79.39%) in November. The mature females (IV

Table IV
Percentage distribution of various stages of maturity in relation to seasons in *S. curvifrons*

Month	Sex	Maturity stage						
		I	II	III	IV	V	VI	VII
July	F	36.12	28.73	—	—	—	2.41	32.74
	M	66.67	33.33	—	—	—	—	—
August	F	33.33	66.67	—	—	—	—	—
	M	33.33	66.67	—	—	—	—	—
September	F	22.22	66.67	11.11	—	—	—	—
	M	25.00	37.50	37.50	—	—	—	—
October	F	8.33	25.00	66.67	—	—	—	—
	M	—	9.09	63.64	27.27	—	—	—
November	F	—	20.11	79.39	—	—	—	—
	M	—	—	58.04	41.96	—	—	—
December	F	—	—	71.28	28.72	—	—	—
	M	—	—	54.54	45.46	—	—	—
January	F	—	—	—	100.00	—	—	—
	M	—	—	—	60.00	40.00	—	—
February	F	—	—	—	16.67	83.33	—	—
	M	—	—	—	30.77	69.23	—	—
March	F	—	—	—	20.00	80.00	—	—
	M	—	—	—	37.50	50.00	12.50	—
April	F	—	—	—	—	90.00	10.00	—
	M	—	—	—	—	25.00	75.00	—
May	F	—	—	—	—	10.00	60.00	30.00
	M	—	—	—	—	—	—	—
June	F	28.58	—	—	—	—	14.28	57.14
	M	50.00	—	—	—	—	10.00	40.00

Table V
Seasonal variations in the gonadosomatic index and the average value of the largest ova in *S. curvifrons*

Month	Gonadosomatic index		Average value of the largest ova (mm)
	Male	Female	
July	1.3	0.9	0.3
August	2.0	1.9	0.6
September	3.4	3.4	1.0
October	4.2	5.1	1.3
November	5.2	5.8	1.4
December	5.6	7.1	1.5
January	5.7	7.6	1.6
February	5.9	8.6	1.6
March	6.3	9.2	1.7
April	6.6	12.0	1.9
May	5.6	9.6	2.1
June	0.9	2.2	2.0

and V stages) were observed from December to May being 100% from January till March. Gravid specimens (Stage VI) occurred from April to July, being maximum (60%) during May. The spent individuals (Stage VII) appeared for the first time in May indicating the commencement of spawning. They were observed till July with the maximum (57.14%) in June. Males too showed an identical trend but generally matured earlier by about a month compared to the females. Some specimens in early stages of maturity (I and II) during June/July observed were either immature or recovering spent ones.

(ii) *Gonadosomatic index:* In females, the gonadosomatic index was minimum (0.9) in July with a gradual rise to 12.0 in April (Table V). A slight decrease (9.6) was noticed in May, followed by an abrupt fall (2.0) in July. A similar trend was observed in gonadosomatic index of male specimens, the difference being only in magnitude.

(iii) *Diameter of ova during different months:* The ova were the smallest in size (0.3 mm) in the month of July (Table V). They increased to 0.6-1.3 mm between August-October while during November-February, they were 1.4-1.6 mm in diameter. From March, an appreciable increase in their size was noticed, reaching the peak (2.1 mm) in May with a slight decrease (2.0 mm) in June and an abrupt fall thereafter.

(iv) *Spawning grounds:* A survey for the location of spawning grounds of *S. curvifrons* was undertaken in Vishaw and Bringi - the upstream tributaries of River Jhelum. The presence of eggs of Schizothoracids in general (density: 57-146 egg m^{-2}) and of *S. curvifrons* in particular (density: 8-31 egg m^{-2}) suggests that the stream beds are the spawning grounds of these fish.

3.10 Relationship between gonadosomatic and gastrosomatic indices at various stages of maturity: In the case of females, from immature stage I up to gravid stage VI, the gonadosomatic index exhibited an increasing trend from 1.5-10.8 which dropped suddenly to 1.8 in spent condition with the release of ova (Table VI). The gastrosomatic index too showed a rise from stage I (4.1) up to stage III (6.4), after which a decrease was recorded in subsequent maturity stages IV-VII (5.5-2.3). In males, the gonadosomatic index exhibited a continuous rise (1.1-7.2) from immature stage I to oozing stage VI with an abrupt fall (0.7) in the spent specimens (Table VI). The gastrosomatic index started rising from stage I (3.6) to stage III (6.8), after which it discerned a decline (3.9-4.2) with marginal fluctuations in IV-VI stages of maturity. A minimum value (2.3) of the index was registered in spent stage.

3.11 Sex ratio: Chi-square value did not reveal any significant departure from 1 : 1 sex ratio in *S. curvifrons* (Table VII). Test of heterogenity also indicated that none of the results departed from 1 : 1 ratio. It was noticed that there were comparatively more males (50.00-81.82) than females among smaller size groups (below 290 mm) whereas in the bigger specimens (above 290 mm), females were abundant (59.45-100.00) (Table VIII).

4. Discussion

From the foregoing account on the maturity studies of *S. curvifrons*, it is apparent that the progression of ova in various stages of maturity exhibited distinct shifting of modes with the

Table VI
Gonadosomatic and gastrosomatic indices at various stages of maturity in *S. curvifrons*

Stages	Sex	Gonadosomatic index	Gastrosomatic index
I	M	1.1	3.6
	F	1.5	4.1
II	M	2.5	6.0
	F	2.5	4.6
III	M	5.0	6.8
	F	4.6	6.4
IV	M	6.4	4.1
	F	5.5	5.5
V	M	6.7	4.2
	F	9.8	4.1
VI	M	7.2	3.9
	F	10.8	3.6
VII	M	0.7	2.3
	F	1.6	2.3

Table VII
Seasonal variations in the sex ratio of *S. curvifrons* with test of significance

Month	Males	Females	Expected numbers in each sex	χ^2	Remarks
July	13	8	10.5	1.19	NS
August	14	17	15.5	0.29	NS
September	16	19	15.5	0.25	NS
October	21	15	20.0	1.00	NS
November	20	13	16.5	1.48	NS
December	16	13	14.5	0.31	NS
January	18	10	14.0	2.28	NS
February	17	10	13.5	1.81	NS
March	15	17	16.0	0.13	NS
April	9	17	13.0	2.46	NS
May	8	16	12.0	2.67	NS
June	10	11	10.5	0.04	NS
Total	177	166	171.5	13.91	

NS=non-significant

Pooled chi-square $\frac{(177 - 166)^2}{177 + 166} = 0.35$

Test of heterogenity	Degree of freedom	
Sum of 12 chi-squares	11	13.91
Pooled chi-square	1	0.35
		13.56
		Non-significant

Table VIII
Percentage frequency of each sex at different size group in *S. curvifrons* during July 1980-June 1982

Size group (mm)	Males (%)	Females (%)
110	66.67	33.33
130	50.00	50.00
150	57.14	42.86
170	81.82	18.18
190	73.33	26.67
210	71.43	28.57
230	54.40	45.60
250	66.26	33.74
270	58.32	41.68
290	53.79	46.21
310	40.55	59.45
330	27.67	72.33
350	28.54	71.46
370	21.06	78.94
390	33 33	66.67
410	—	100.00

advancement of each stage. The maximum size of ova attained in VI stage of maturity was 2.4m when they were ready to be shed. No other developing batch of ova was found in the ripe ovary which indicated that the spawning was restricted to once during the breeding period. This was further substantiated by the investigations on gonadosomatic index, maturity cycle and average diameter of 25 large sized ova which are considered to be the important tools for providing a good indication of the extent of development of gonads with respect to the time of the year and establishing the spawning season of the fish species[7-10]. In the case of other Schizothoracids too a single restricted spawning period has been recorded by earlier workers[1,4,11]. The progression of ova size in *S. curvifrons* was maximum during post-spawning months (July-November) and less during winter months followed by the pre-spawning phase as reported for *Oreinus plagiostomus* by Mir[11].

A comparison between gastrosomatic and gonadosomatic indices indicates that the highest values of gonadosomatic index were observed in gravid stage coinciding with low values of gastrosomatic index exhibiting the feeding activity to be much reduced during spawning season. However, the gonadosomatic indices were the lowest in the spent condition of the fish as recorded by various workers[7-9]

The rate of growth of ovaries in relation to the total length of fish was slightly faster ($b=0.3572$) than those of testes ($b=0.3476$) in *S. curvifrons*. Saigal[10] also recorded similar observations.

S. plagiostomus and *S. esocinus* mature at a size of 300 and 370 mm respectively[12] Jyoti and Malhotra[13] recorded that one year old *S. niger* attains maturity at 135 mm. In the case of *S. curvifrons*, the data analysed for size at first maturity revealed that female specimens below 190 mm were immature and practically all the fish at a size of ≥ 310 mm

were mature. This was supported by the presence of a spent female specimen measuring 194 mm in the fish samples examined. Moreover, males of *S. curvifrons* matured at an earlier size and about a month earlier than those of the females. In several species of fish, the males ripen earlier and reach the spawning grounds before the females[14]

Acknowledgements

The author is grateful to the Director, Central Inland Fisheries Research Institute, Barrackpore for his kind encouragement and to Dr. B.A. Subla, Centre of Research for Development, Srinagar for his keen interest in the work.

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