

5.1. Introduction

Reproduction is the process by which species are perpetuated. The success of any fish species is ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment (Moyle & Czech, Jr., 2000). Therefore the reproductive strategy as reflected in anatomical, behavioral, physiological, and energetic adaptations is an essential commitment to future generation. It is also a continuous development process throughout ontogeny, requiring energetic, ecological, anatomical, biochemical and endocrinological adaptations. The reproductive behaviour in fishes is remarkably diversified. Most fishes lay a large number of eggs, fertilized in the aquatic environment.

Studies of reproduction and growth of many species indicated that the reproductive cycle of fishes are closely tied to the environmental changes particularly temperature, day length and food supply. These environmental factors have the greatest influence upon the gonadal development initiation and fecundity of the species. The effect of the two former factors on the reproductive cycle of mudsucker *Gillichthys mirabilis*, was demonstrated by (De Vlaming, 1972a; 1972b). Reproductive parameters such as size at first maturity, spawning frequency, fecundity, sex ratio, and

recruitment are of great value in fishery prediction and formulation of management measures (Bal and Rao, 1984).

Information on fish reproduction is also important in aquaculture. The availability of quality seeds and the ability to control fish reproduction are limiting factors in the farming of any commercial species. This became an important factor to fulfill the demand of continuity in supply of table fish and fish seeds throughout the year. Sufficient information related to reproductive parameters and developmental biology can only meet this requirements. The successful adoption of induced breeding technique, using pituitary hormone, for a number of important species may play an important role in improving the fish seed supply in aquaculture.

Studies on the reproductive biology of commercially important fishes from Indian waters have been successfully carried out by many authors. Amongst the notable contributions are of Radhakrishnan (1957); Qasim & Qayyum (1963); James (1967); Khan (1972); Qasim (1973); Sreenivasan (1979); Gowda *et al.* (1988b); Guha & Mukherjee (1991); Jayasankar and Alagarwami (1993); Das Gupta (2002); Doddamani *et al.* (2002) and Manojkumar (2005).

Information available on the reproductive biology of the estuarine fish *S. sihama* from Indian waters, particularly from Goa waters is scanty. Therefore a detailed investigation on various aspects of reproduction was

carried out in the present study. This study covered maturity stages, development of ova to maturity, spawning season, gonado somatic index, size at first maturity, sex ratio and fecundity of *S. sihama* from Goa water.

5.2. Material and Methods

Fish samples were collected at fortnightly intervals from Zuari estuary (off Dona Paula) over a period of 15 months (January 2004 - April 2005). The samples were cleaned and the surface moisture was removed using tissue paper in the laboratory. Each fish sample was measured for its total length to the nearest 1 mm and total weight to the nearest 1.0 g. The sex of individual specimen was determined by observing the gonads after dissecting the specimens, as there is no sexual dimorphism in this fish. Maturity stages of each gonad were recorded. The gonads were dissected out and preserved in 5 % formaldehyde for further studies.

5.2.1. Stages of maturity

Stages of maturity of gonads were determined on the basis of morphological appearance (macroscopic observations) in males. Macroscopic as well as microscopic observations were used in case of females, following the standards laid down by international council for exploration of sea (Lovern and Wood, 1937) and given in Jayasankar

(1991b). While macroscopic observations were based on fresh samples, microscopic observations were based on materials preserved in formaldehyde.

5.2.2. Ova development

Intra-ovarian egg diameter was measured using an ocular micrometer with magnification of 0.01 mm to each ocular micrometer division (O.M.D). For the detailed studies of ova, samples from anterior, middle and posterior regions of the ovary were taken in all measurements in the present study. Ova less than 5 μ m divisions were not measured since they were present in ovaries of all maturity stages. Ova were grouped into three O.M.D intervals. The ova diameter frequencies from the ovaries of the same maturity stages were pooled and plotted.

5.2.3. Spawning frequency

Frequency of spawning was determined based on the modes of ova diameters in the mature ovaries, following Jayabalan (1986).

5.2.4. Spawning season

Spawning season was determined on the basis of distribution of different maturity stages of male and female during different months.

5.2.5. Gonado Somatic Index (G.S.I.)

G.S.I. was also used to determine the spawning period following the formula given by Qasim (1973):

$$G.S.I. = \frac{\textit{Weight of gonad}}{\textit{weight of fish}} \times 100$$

The G.S.I. was calculated for both sexes. The average G.S.I. value for each month and size group was also calculated.

5.2.6. Size at first maturity

Fishes belonging to maturity stage III onwards have been considered as mature fish and used for the purpose of calculating the size at first maturity. Data for 15 months were pooled together. The percentage of the mature fish in relation to immature fish in different size group was determined. The length at which 50 % of fish were mature was considered as length at first maturity (Lm) of both sexes, by the frequency occurrence of different stages of maturity in various size groups.

5.2.7. Sex ratio

Sex ratio was calculated for different months and size groups of the fish. The sex ratio was tested for equality for different months using Chi-square test.

5.2.8. Fecundity

Fecundity was studied by examining 30 mature preserved ovaries. A small portion was cut from the anterior, middle and posterior regions of the ovary and considered as one sample. After recording the weight, the sub samples were teased out and dispersed in a small amount of water. The mature ova were counted and the total number of ova was computed based on the total weight of the ovary using the formula:

$$F = \frac{\text{No of ova in the sample} \times \text{Total weight of ovary}}{\text{Weight of the sample}} \times 100$$

The relationship between fecundity and total length, total weight and weight of ovary was statistically determined.

5.3. Results

The reproductive strategies of fishes are often reflected in the anatomical differences between sexes. The sexes of most fishes can be easily distinguished by examination of their gonads. Like most of other teleostean, the reproductive glands (testes of males and ovaries of females) of *S. sihama* are typically paired structures. Both the testes and ovaries are suspended by mesenteries across the roof on the sides of the body cavity, in close association with the kidneys. The means of passing sperms from testes and eggs from ovaries are vas deferens and oviducts,

respectively. They combine to form a common duct (sperm duct in male and ovarian duct in female), and open to the exterior by a common genital aperture. In general the reproductive organs in *S. sihama* are paired and symmetrical, although cases of asymmetry were also encountered.

5.3.1. Classification of maturity stages

In fishes which are less than 95 mm total length, gonads are minute and translucent; hence sex of such fishes is difficult to be determined. Gonads of adult fishes were classified into five maturity stages based on gonads morphology in male and female, in addition to intra-ovarian ova in female. The classification of maturity stages of *S. sihama* is presented in Table 5.1., Plates 5.1. and 5.2.

5.3.1.1. Maturity stages in Male

Stage I (Immature): Testes are small, thin, and thread-like in shape.

Stage II (Maturing): Testes are semitransparent, dark gray, and extending upto less than $\frac{1}{2}$ of the abdominal cavity. As testes developed they became moderately thick, slightly flattened, and gray-whitish extending upto $\frac{1}{2}$ of the abdominal cavity in the early phases and upto $\frac{2}{3}$ of the abdominal cavity in the late phases.

Table 5.1. Classification of different maturity stages in *S. sihama*.

Maturity stage	Description	Mode of ova diameter(mm)	Maximum diameter of ova (mm)
Stage I	Immature	0.05 - 0.08	0.20
		0.08 - 0.17	
Stage II	Maturing	0.08 - 0.11	0.38
		0.17 - 0.20	
		0.29 - 0.32	
Stage III	Mature	0.14 - 0.17	0.48
		0.23- 0.26	
		0.29 - 0.32	
		0.35 - 0.38	
Stage IV	Ripe	0.17 - 0.20	0.64
		0.23 - 0.26	
		0.35 - 0.38	
Stage V	Spent	0.44 - 0.47	0.44
		0.05 - 0.08	
		0.17 - 0.20	

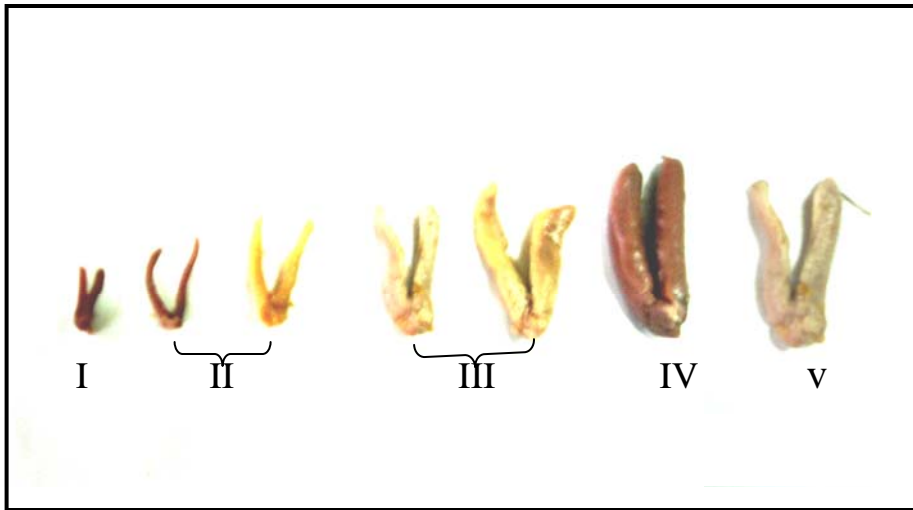


Plate 5.1. Ovary of *S. sihama* in different maturity stages.

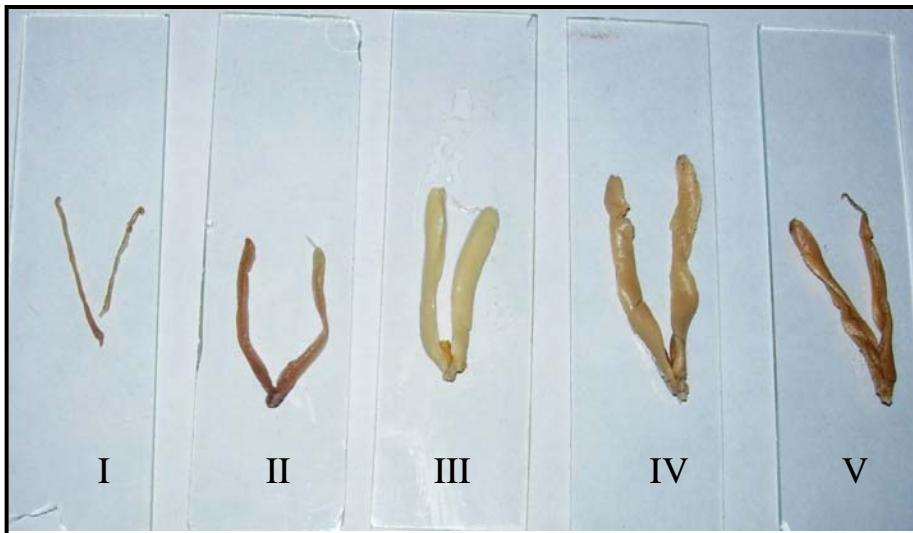


Plate 5.2. Testes of *S. sihama* in different maturity stages.

Stage III (Mature): Testes are large, opaque, well developed and white or ivory in colour. They are ribbon shaped, occupying about $\frac{2}{3}$ – $\frac{3}{4}$ of the body cavity.

Stage IV (Ripe): They look like mature testes thick, flat but more swollen, creamy white, extending in the entire body cavity.

Stage V (Spent): Testes are shrunken, opaque and strap-like. They turned back upto $\frac{2}{3}$ body cavity.

5.3.1.2. Maturity stages in Female

Stage I (Immature): Ovaries are small, thin, occupying less than $\frac{1}{2}$ of the abdominal cavity. They are usually translucent pink or glassy. The oocytes are minute (microscopic) resulting in a smooth appearance to the ovary tissue. All the ova are immature with a mode at (0.05 - 0.08 mm).

Stage II (Maturing): The ovaries developed in size to occupy about $\frac{1}{2}$ - $\frac{2}{3}$ of the body cavity. They appear as a semi translucent to clear yellow and oval in shape. It showed withdrawal of a batch of ova with a mode at 0.19 mm, another mode at 0.31 mm was representing the maturing ova.

Stage III (Mature): As more oocytes developed and turn opaque, the ovaries turn to pale yellow or apricot colour. The opaque oocytes are visible through the thin gonad wall. At this stage ovaries extending upto more

than $\frac{3}{4}$ of the body cavity. The mature group of ova was well differentiated from immature, maturing groups with mode at 0.37 mm.

Stage IV (Ripe): ovaries are very large and swollen; filling the entire body cavity. Colour is orange with a prominent net work of blood vessels. Granular appearance is an important salient of the ovary at this stage. All the type of ova was observed; well developed ripe ova formed a distinct mode at 0.47 mm.

Stage V (Spent): Soon after completion of spawning activity, the spent ovaries appear flaccid with a prominent blood vessels and reddish yellow in colour. Few oocytes can be seen, whilst yellow- brown bodies may be evident for sometime and are the main feature used to distinguish spent ovary from immature or early maturing ovaries.

Various workers have adopted different types of classification for the intra-ovarian eggs. Hyndes *et al.* (1996) suggested four stages of oocytes in the ovaries of *S. bueeus* and *S. vittata* namely prenuclear, yolk-vesicle, yolk granule oocytes and hydrated eggs. Following this classification the ova could be distinguished in the ovaries of different stages of maturity in the present study are shown in Plate 5.3., and they are:

Pre-nuclear ova (Immature): Transparent ones with a prominent central nucleus. The protoplasm is devoid of any yolk accumulation. The size of

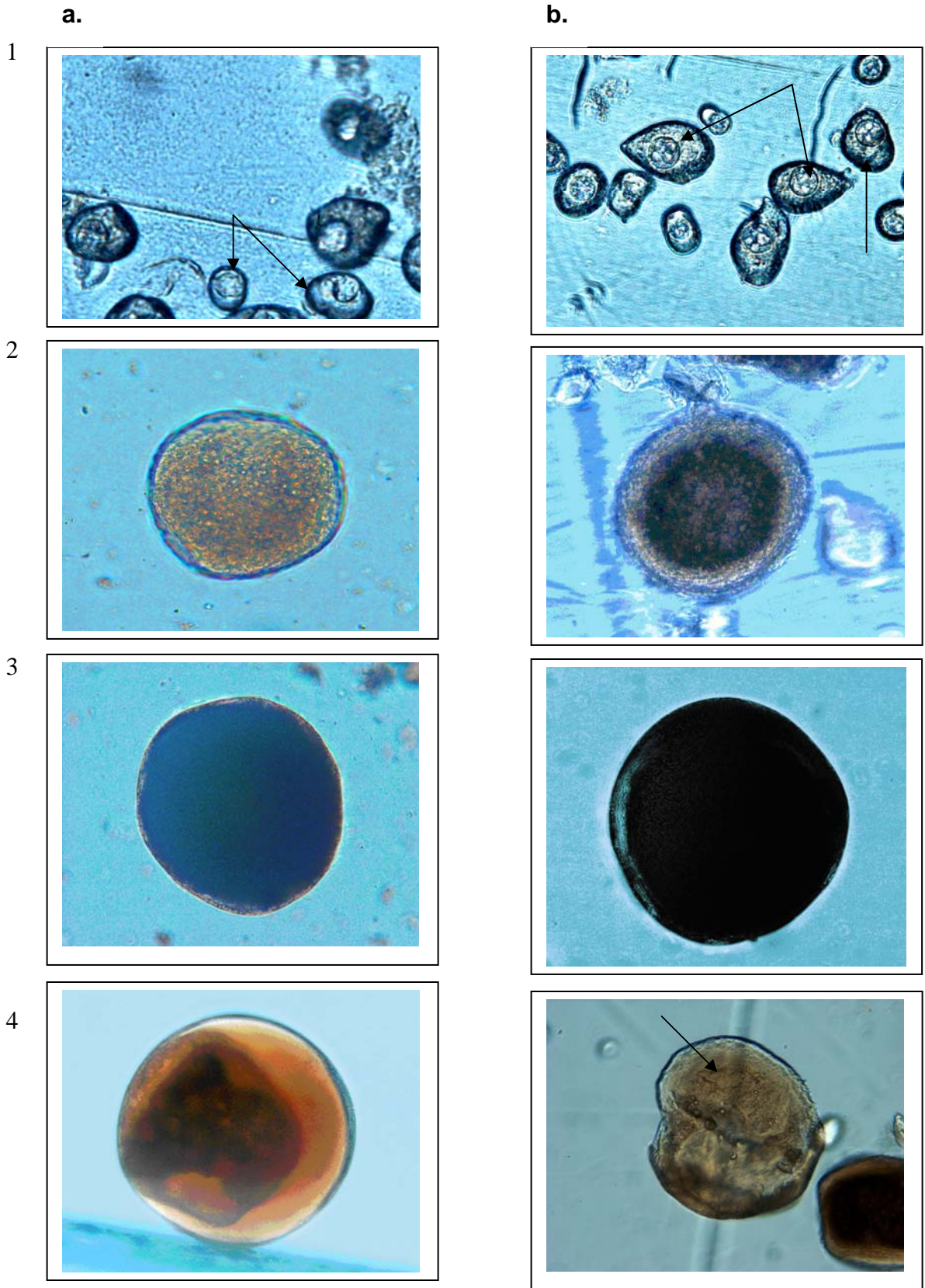


Plate 5.3. Different types of oocytes in the ovary of female *S. sihama*: **a.** (early stage); **b.** (Late stage). 1. Immature ova; 2. Maturing ova; 3. Mature ova & 4. Ripe ova.

ova ranged between 0.02 and 0.05 mm in early stage. With the increase in size upto 0.08 - 0.17 mm, a number of nucleoli can be seen at the periphery of the nucleus. Few ova attain upto 0.20 mm in diameter.

Yolk-vesicle ova (Maturing): Small, opaque in which the yolk deposition just started. Semitransparent area can be made out in the center with partially visible nucleus. The early maturing ova which are not fully yolke, the diameter varies from 0.14 - 0.22 mm. With increase in yolk accumulation the ova became opaque, spherical shape with diameter from 0.22 - 0.35 mm.

Yolk granule ova (Mature): Large, opaque, spherical with slight elongation in some cases. Full yolke and still contained within the follicles. The size ranged between 0.32 - 0.44 mm, upto 0.47 mm in few instances.

Hydrated eggs (Ripe): Fully mature, large, fully or partially transparent which have burst from the follicles. The majority of ova varied in diameter from 0.44 to 0.50 mm, very few instances were found upto 0.62 mm.

5.3.2. Development of ova to maturity

The diameters of ova from representative ovaries of the five maturity stages were measured. The size frequency distribution of ova in the

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stages I - V of maturity are shown in Fig. 5.1. The frequency polygons of ova diameters of various maturity stages showed that in stage I (immature ovary), majority of the ova were 0.05 - 0.08 mm (representing the immature stock of ova), and a few ones measured upto 0.20 mm. The immature stock of ova was found in all the subsequent stages. In Stage II (maturing ovary), a batch of ova separated from the general stock forming a mode at 0.08 - 0.11 mm, another distinct mode at 0.17 - 0.20 mm forming the first batch of maturing ova was also formed. In stage III (mature ovary), the first batch of maturing ova which appeared in stage II, developed further and formed a mode at 0.20 - 0.23 mm. In addition a new batch of maturing ova with mode at 0.14 - 0.17 mm made its appearance. At this stage the mature group of ova was well demarcated from maturing and immature ones by a mode at 0.35 - 0.38 mm. Stage IV (ripe ovary), contained all the four stages of ova. The mature group of ova with mode at 0.35 - 0.38 mm, which found in stage III, grew further and reached a mode at 0.44 - 0.47 mm, these ova were ripe and were ready for spawning. In addition to this group, modes at 0.32 - 0.35 mm representing the mature ova, 0.17 - 0.20 mm and a fraction at 0.23 - 0.26 mm were also took place. In stage V (spent ovary), the ripe ova that had been at 0.44 - 0.47 mm in stage IV were already extruded, and there were only immature, maturing and few residual of mature ova. Generally, the maturing and mature ova are passed in succession to advanced maturity stages and fresh batches of maturing ova separated from the immature stock.

5.3.3. Spawning frequency

As can be seen from Fig. 5.1. in an advanced stage of ovary three distinct groups of maturing and mature ova at 0.17 - 0.20, 0.32 - 0.35 and 0.44 - 0.47 mm are separated from the immature ones. As the fish approaches the spawning season, the most advanced group of ova at 0.44 - 0.47 mm were separated distinctly and are released from the follicular chamber, by the time the next group at 0.035 - 0.038 mm are approaching the ripe stage and became ready to release in the same spawning season. The maturing groups of ova which had undergone half the maturation process are also expected to be released in a single spawning season.

5.3.4. Size at first maturity

To determine the size at which the fish attain the first sexual maturity a total of 656 males and 754 females were used. The percentage occurrence of matured individuals was plotted against different size group in male and female and presented in Fig. 5.2. It showed that both sexes became matured at the size group 155 - 164 mm total length (mid point, 159.5 mm). About 90.9 % of the total numbers of males were matured at size 165 - 174 mm; all males were matured at size 175 mm onwards. In female 94.7 % of total number were matured at size 175 - 184 mm and

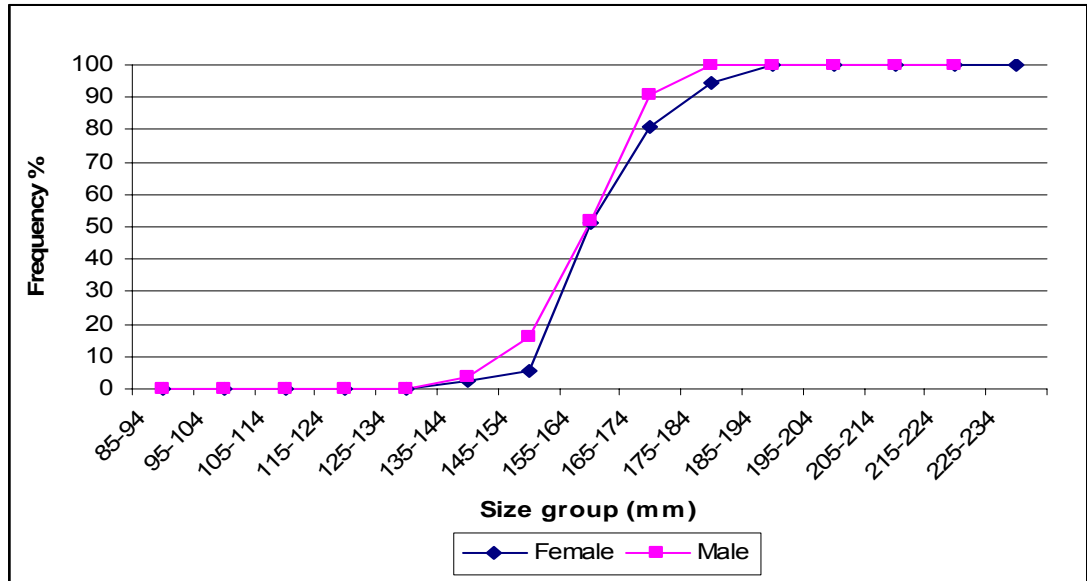


Fig. 5.2. Percentage occurrence of male and female *S. sihama* in different size groups.

from 185 mm onwards all the females were fully matured. The smallest size at which mature specimens were found was 138 mm and 135 mm in male and female, respectively.

5.3.5. Spawning season

Spawning season was determined on the basis of occurrence of different maturity stages of male and female in each month during the period from January 2004 to April 2005. The results are shown in Fig. 5.3. The females in stage III with mature gonads appeared round the year except in March 2004, while females with stage IV gonads were observed during period lasted from June to December and few were found in February. Spent individuals (stage V) were observed in small percentage in March, May, July - August and October. The percentage occurrence of spent gonads was higher by the end of November, sharply increased in December followed by decrease in January. Virtually, fishes with immature (I) and maturing (II) gonads were present all round the year which indicate a protracted breeding behaviour.

Similar trends were also noticed in males. The peak of occurrence of individuals with ripe gonads lasted from September to November. Spent males were found in May, July to January with peak in December.

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From the above observations it is clear that the major spawning season in *S. sihama* lasts from June to December with peaks spawning activity from September to November.

5.3.6. Gonado Somatic index (G.S.I.)

The monthly G.S.I. of male and female are given in Fig. 5.4. The mean monthly G.S.I. in male fluctuated between 0.10 in April to 1.03 in November and in female from 0.25 in May to 3.76 in September. The values of G.S.I. increased from June to December showing two distinct peaks in September and November in both the sexes. The peak value in G.S.I. coincided with peak spawning period thus showing a close relationship between the two.

5.3.7. Sex ratio

The data on sex ratio is depicted in Table 5.2. The ratio of males to females was found to be 1:1.17. Test of significance of difference revealed that in September and November 2004 and in January - March 2005 the proportions of males and females differ significantly ($\chi^2 = 7.49$, $P < 0.01$; $\chi^2 = 11.58$, $P < 0.001$; $\chi^2 = 8.49$, $P < 0.01$; $\chi^2 = 5.54$, $P < 0.05$; $\chi^2 = 9.35$, $P < 0.001$, respectively). In other months the difference was insignificant. The Chi-square test of pooled data did not show any significant difference ($\chi^2 = 3.13$, $P < 0.05$).

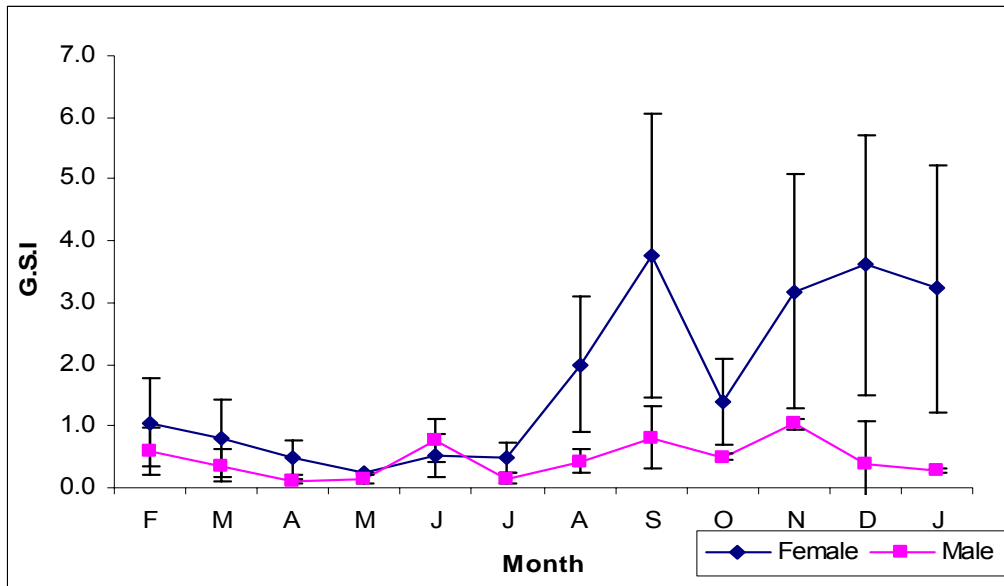


Fig. 5.4. Monthly mean G.S.I. \pm SD values of *S. sihama* during February 2004 – January 2005.

Table 5.2. Monthly variation in Sex ratio of *S. sihama* during February 2004 - April 2005.

Month	Total no.	No. of Males	No. of Females	Ratio M : F	X ²
Feb	77	38	39	0.97 : 1	0.01
Mar	98	46	51	0.90 : 1	0.27
Apr	111	51	60	0.85 : 1	0.73
May	101	49	52	0.94 : 1	0.09
Jun	82	38	44	0.86 : 1	0.44
Jul	112	56	56	1.00 : 1	0.00
Aug	99	49	50	0.98 : 1	0.01
Sep	77	50	26	1.92 : 1	7.49**
Oct	50	23	27	0.80 : 1	0.32
Nov	83	26	57	0.46 : 1	11.58***
Dec	84	43	41	1.00 : 1	0.05
Jan	106	38	68	0.56 : 1	8.49**
Feb	104	40	64	0.63 : 1	5.54*
Mar	131	48	83	0.58 : 1	9.35***
Apr	87	51	36	1.4 : 1	2.59

** P < 0.01, *** P < 0.001

Critical value χ^2 3.84, 0.05, 1 DF

Table 5.3. Variation in Sex ratio of different size group.

Size class	Total no.	No. of Males	No. of Females	Ratio M : F	χ^2
85-94	3	1	2	0.5 : 1	0.33
95-104	44	27	17	1.59 : 1	2.27
105-114	183	76	107	0.71 : 1	5.25*
115-124	242	132	110	1.20 : 1	2.00
125-134	336	178	158	1.13 : 1	1.19
135-144	203	80	123	0.65 : 1	9.11**
145-154	153	57	96	0.59 : 1	9.94**
155-164	135	54	81	0.67 : 1	5.40*
165-174	70	22	48	0.46 : 1	9.66**
175-184	25	10	15	0.67 : 1	1.00
185-194	12	4	8	0.50 : 1	1.33
195-204	6	2	4	0.50 : 1	0.67
205-214	8	3	5	0.60 : 1	0.50
215-224	5	2	3	0.67 ; 1	0.20
225-234			3		

* P < 0.05, ** P < 0.01, *** P < 0.001

Critical value χ^2 3.84, 0.05, 1DF

The data on sex ratio in relation to size group is given in Table 5.3. It suggests that females outnumbered males in all the size groups except in 95 - 104, 115 - 124 mm and 125 - 134 mm. The Chi-square test values were found to be significant from 135 - 144 to 165 - 174 mm size groups ($\chi^2 = 5.40$, $P < 0.05$; $\chi^2 = 9.94$, $P < 0.01$).

5.3.8. Fecundity

Data on observed and calculated number of mature eggs produced by ovaries of different sizes is shown in Table 5.4. The total number of mature eggs varied from 11376 to 103695 in individuals of 150 mm to 342 mm. The mean fecundity value of 30 specimens was 42575 ± 4730 .

The relationships between Fecundity and total length, weight of fish and weight of ovary are shown in Fig. 5.5. It showed the best fit by a logarithmic equation as:

$$\text{Log } F = - 2.0112 + 2.8971 \text{ Log } L$$

Where F = Fecundity and L = total length of fish.

The fecundity and weight of fish (g) relationship can be expressed in the form of:

Table 5.4. Observed and calculated fecundity of *S. sihama*.

Total length (mm)	Total weight (g)	Ovary weight (g)	Observed fecundity	Calculated Fecundity		
				$F = a L^b$	$F = a W^b$	$F = a O^b$
150	22.11	0.33	15187	19573	16786	11124
153	26.64	0.75	16736	20724	20300	21753
155	27.51	0.29	11376	21515	20977	10010
156	26.73	0.34	14082	21918	20370	11399
157	31.29	0.99	13600	22325	23920	27291
158	25.09	0.55	16749	22738	19096	16884
158	28.39	0.67	17107	22738	21661	19838
160	27.8	0.92	18277	23578	21202	25704
160	29.1	1.46	26476	23578	22214	37484
161	32.56	1.014	24480	24005	24911	27830
162	34.2	1.02	25385	24438	26191	27965
169	36.78	1.23	25461	27609	28208	32586
169	38.52	1.33	32890	27609	29569	34734
170	39.82	1.95	35295	28082	30587	47480
170	38.36	2.41	43192	28082	29444	56449
175	43.82	2.46	46565	30531	33724	57404
181	50.05	1.37	37888	33648	38621	35585
183	45.59	1.74	44863	34732	35114	43260
184	44.45	2.28	41873	35282	34219	53949
187	49.64	1.1	32646	36967	38298	29744
189	50.44	1.7	45666	38119	38928	42446
190	44.54	2.12	46514	38703	34289	50836
194	59.78	1.76	59546	41100	46292	43666
194	54.28	1.66	57720	41100	41953	41629
197	63.43	2.03	63600	42960	49177	49066
212	80.19	3.29	83750	53085	62461	72792
225	72.77	2.22	83336	63025	56572	52786
228	79.58	1.11	73661	65479	61977	29965
286	166.13	3.35	92250	125887	131291	73874
342	257.67	4.46	103695	210839	205421	93331
Average			41662.2	41666	42126	39296

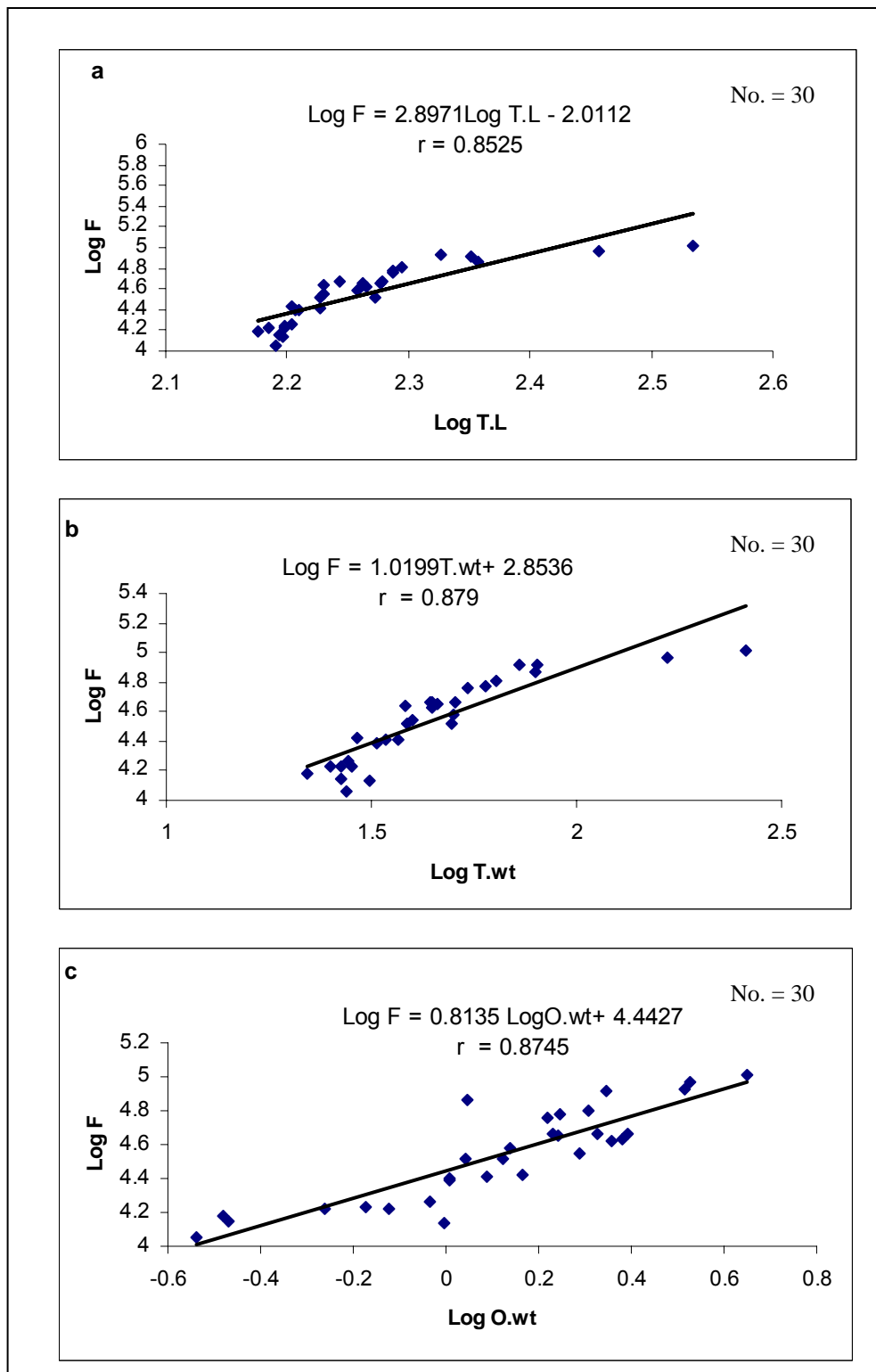


Fig. 5.5. Relationship of fecundity of *S. sihama* with total length (a), total weight (b) and ovary weight (c).

$$\text{Log F} = 2.8536 + 1.0199 \text{ Log W}$$

Where F = Fecundity and W = weight of fish.

The relationship between Fecundity and weight of ovary (g) can be expressed in form of next regression equation:

$$\text{Log F} = 4.4427 + 0.8135 \text{ Log w}$$

Where F = Fecundity and w = weight of ovary.

From the scattered diagrams of relationship between fecundity and total length, weight of fish and weight of ovary, it can be seen that there was linear relationship between fecundity and the three variables. Fecundity increased at the rate of 2.8971, 1.0199 and 0.8135 times of the total length, weight of fish and weight of ovary, respectively. Positive correlation was observed between fecundity and total length, weight of fish and weight of ovary. The correlation coefficient values were $r = 0.7268$, ($P < 0.05$); $r = 0.7726$, ($P < 0.05$); $r = 0.7648$, ($P < 0.05$), respectively.

5.4. Discussion

5.4.1. Spawning frequency

Presence of three distinct modes of ova in mature ovary besides the immature stock indicates that *S. sihama* from Goa waters spawns more than once in a single spawning season.

The result supports those found out by James *et al.* (1976) and Jayasankar and Alagarwami (1993) on the reproductive of *S. sihama* from south Kanara district and Palk Bay and Gulf of Mannar, respectively. Similar observations were reported in *Trenched sardine*, *Sardinella sirm* (Lazarus, 1990), *S. burrus* and *S. vittata* (Hyndes, 1996), *Gobioides rubicundus* of the Bay of Bengal (Kader *et al.*, 1988), *Etroplus suratensis* of India and Sri Lanka (Pathiratne and Costa, 1984). There are many advantages of multiple spawning. It increases the total number of eggs produce in a single spawning season, spreads the risk of eggs and larval predation over a long period (Blaber, 2000). At the same time it acts to buffer any short-term adverse fluctuation in the abundance of suitable planktonic larval food that may appear in different months.

5.4.2. Spawning season

Coastal or estuarine fishes in the tropics and sub-tropics are mainly serial spawners with a protracted spawning season (Longhurst and Pauly, 1987; Houde, 1989) in contrast to species in temperate regions. The stimuli of the onset of reproduction in any tropical estuarine fishes are less clear than fresh water and tropical reef species. This is perhaps because of the general variety of biotic and abiotic influences of marine, estuarine and freshwater origin that come together in this environment (Blaber, 2000). However, spawning usually occur at a time when environmental conditions

are most favorable for larval survival and development. Temperature plays an important role in triggering spawning in tropics.

It is clear from Fig. 5.3. that mature gonads were found throughout the year. However, the percentage frequency of mature gonads was higher during June- December. Spent individual were also noticed in most part of the year and the highest percentage in December. This suggests that *S. sihama* has a prolonged spawning season extending from June to December. The highest spawning activity was observed during September and November in both the sexes. These observations are further supported by G.S.I. values. In the present study, high values of G.S.I. denoted attainment of peak maturity of gonads. Hence the coincidence of occurrence of stages III and IV with high G.S.I. values indicate that the peak spawning takes place during June to December. These observations corroborate the earlier reports of Gowda *et al.* (1988); Jayasankar (1991), and Reddy (1991) in *S. sihama* from Indian water.

5.4.3 Size at first maturity

The size and age at first maturity depends on the nature of the environment in which the population of concern lives (Moyle & Czech, 2000).

Knowledge on the size at first maturity of fish helps to predicts harvestable size of the fish. Hence it has great benefits in fishery as well as

aquaculture In the present study it is convenient to consider 155 - 164 mm size group as the size by which both the sexes attain sexual maturity when they are ≥ 2 years old. Slightly different values regarding the size at first maturity of *S. sihama* were observed by others Radhakrishnan (1957) reported first maturity at 130 mm; James *et al.* (1976) at 151 -191 mm; Krishnamurthy and Kaliyamurthy (1978) at 140 - 145 mm and Jayasankar (1991) at 170 – 175 mm. The present observations are very close to the observations made by James *et al.* (1976) and Krishnamurthy and Kaliyamurthy (1978).

Most teleosts are itroparous, means they spawn more than once during their lives. In the present investigation, *S. sihama* attains maturity when it is ≥ 2 years old and the largest specimens found were ≥ 3 years old. This means the species spawn more than once during its life. Hyndes *et al.* (1996) compared the size and age at maturity among sillaginids, and found that *S. burrus* did not live for more than 2 years and never exceeded 4 years age. It attains maturity at the end of its first year at 130 mm length, *S. vittata* reached 2 years of age and some individuals lived for 4 - 7 years. It attains maturity at, size of 130 mm. Comparing with findings of Hyndes and Potter (1996), *S. bassensis* do not reach maturity until the end of its third year of life; by which time it exceeds 200 mm in length, while *S. robusta* grows to a size similar to those of *S. burrus*, but does not reach first maturity until the end of second year of life which is the case with *S. sihama*. The comparison emphasize that the relationship between

the size and age at first maturity vary considerably amongst whiting species, distributed in different geographical areas. This could be attributed to habitat variability and environmental factors.

5.4.4. Sex ratio

Sex ratio indicates the proportion of male and female in the population and is expected to be 1:1 in nature. Any deviation from this ratio may indicate the dominance of one sex over the other. This happens because of differential behaviour of sexes, environmental conditions, fishing, etc. (Bal and Rao, 1984). The monthly distribution of two sexes in *S. sihama* did not show a significant difference in the distribution of both sexes except in September 2004 when males were dominance over females, November 2004 and January – March 2005 when females were dominance over males. However, the overall male: female ratio was 1:1.17. The Chi-square value did not show any significant difference indicating equal distribution of both sexes. Jayasankar (1991) reported a sex ratio of 1:1.1 (male:female) in *S. sihama* from Palk Bay and Gulf of Mannar. Chatterji (1976) reported a ratio of 1:1.4 in major Carp, which did not deviate significantly from the hypothetical distribution.

Comparing with G.S.I. values, it is inferred that during November 2004 and January – February 2005 the G.S.I. was high in female and relatively lower in male. That may indicate higher spawning activity of female at the time of sampling leading to aggregation of females in the spawning

ground, while, in September dominance of males may be related to predominance of maturing males of a particular size. Related to size and age, females appeared to be predominant in larger size groups.

5.4.5. Fecundity

Fecundity is the most common measure of reproductive potential in fishes. In order to maintain the position of any species in an environment, it required to reproduce to such an extent that would enable it to counteract all physical and biological hazards such as predation, critical stages of its life history, food supply, etc. (Qasim and Qayyum, 1963).

In general, fecundity increases with the increase in the size of female, which can be expressed by $F = a L^b$ (Bagenal, 1978). This means that larger fishes produce considerably more eggs than do smaller fishes. In the case of *S. sihama* the linear relationship between fecundity and total length of the fish suggests that the fecundity increases at the rate of 2.987 times the total length. The linear relationships were also noticed between fecundity and weight of fish and ovary weight. The linearity in such relationships have been also proved by many scientists (Palekar and Bal, 1961; Gowda, 1988b; Jayasankar, 1991; Reddy and Neelakantan, 1991) in *S. sihama*, Chatterji and Ansari (1982) in Dolphin fish *Coryphaena hippurus*, Zacharia and Nataraja (2003) in Threadfin bream, *Nemipterus mesoprion* and Manojkumar (2005) in *Decapterus russelli*.

There is variation in the estimated value of fecundity reported by different workers in *S. sihama*. Radhakrishnan (1957) stated that a fully mature ovary of *S. sihama* produce 14000 eggs, while Palekar and Bal (1961) reported fecundity in the range of 16682 to 166130. The fecundity of *S. sihama* reported by other workers (James *et al.*, 1976; Krishnamurthy and Kaliyamurthy, 1978; Gowda, 1988; Jayasankar, 1991; Reddy and Neelakantan, 1993) were 11304 - 100593, 31678 - 288000, 49862 -1670477, 6956 - 48373 and 20184 - 12045 eggs, respectively. There are many factors that complicate the interpretation of fecundity data. These are fertility, the frequency of spawning, parental care, egg size, population density and environmental factors (Bagenal, 1978).

The present study revealed that *S. sihama* spawn intermittently throughout the year with a wide size range of matured ova in the ripe ovaries. Like most of estuarine fishes the spawning period commence with the beginning of the monsoon season. It attains the sexual maturity at 155 - 164 mm length; produce a large number of eggs as an adaptation to the extreme environment. Total length can be considered as a better indicator of fecundity than weight of fish and weight of ovary in *S. sihama*.

6.1. Introduction

Typically, growth can be defined as the change in size (length, weight) over time. However, it can energetically, defined as the change in calories stored as somatic and reproductive tissues. The latter definition is useful for understanding the factors that affect growth because of conversion of the ingested food energy into metabolic or growth or excreted energy (Brett and Groves, 1979). Although, most of fish continue to grow throughout their lives, growth is not constant over the years. Consequently, growth has been one of the most intensively studied aspects of fish biology. It is a good indicator of the health of individuals and populations.

The growth rate is an important parameter that influences population dynamics in fishes (Bal and Rao, 1984; Seshappa, 1999). The growth rate is variable because it is greatly dependent on a number of biotic factors such as age, maturity, ingested food quality and quantity and presence of the predators. It is also influenced by abiotic factors, such as temperature, photoperiod, dissolved oxygen and salinity. All these factors interact with each other to influence the growth rate.

Growth is expressed in relation to time, thus it is useful to determine the age of the candidate species. There are two main methods to determine the age of fish e.g. the direct method by rearing the fish in tanks or aquaria or by tagging fishes. The other method is indirect determination of age which is applied in two ways, those are length frequency distribution method and by interpretation of the growth rings on the hard parts.

For species that can be aged, growth is directly determined from size at age or back-calculation from scale readings. In species can not be aged, other methods such as length frequency distribution may be used to estimate the growth rate by treating length as a non – linear measure of biological time (Jennings *et al.*, 2001).

Separation of the complex length frequency distribution for the whole population into cohorts and assign age to them is the aim of estimating growth from length frequency distribution (Jennings, *et al.*, 2001). This method also called as Petersen's length frequency polygon method. In the tropical fishes those breeds over a prolonged period, length frequency distribution is seldom applicable because of the entry of broods into the population several times in a year (Qasim, 1973).

Fortunately, many fishes carry records of time (age) on their hard parts. The hard parts that usually used for age determination are the scales, otolith, vertebral centra, dorsal and pectoral spines operculae, etc. However, the growth rings are known to be more distinct and clear on the

otolith than in other structure of the fish. Therefore, they are extensively used to determine the age in fishes (Jennings *et al.*, 2001; David and Pancharatna, 2003). This method of aging is based on the fact that successive rings are formed as the fish grows in age.

Knowledge of a mathematical relationship between the length and the weight of the fish in a given geographical area is a practical index of the condition of fish (Petrakis and Stergiou, 1995). Hence weight of a given fish of known length or length classes can be calculated. A life history and morphological comparison of populations from different regions can be made from length weight relationship (Goncalve *et al.*, 1997). Similarly, calculating standing stock biomass and several other aspects of population dynamics can be estimated using length weight relationship (Morato *et al.*, 2001).

The principle of the length weight relationship is that the weight of the fish increase in relation to increase in its length. Theoretically, it can be described using a power function of the formula $W = a L^b$ (Le Cren, 1951) where 'a' and 'b' are constants. In nature, the body proportions of a fish continually change with aging. The form and specific gravity do not remain constant throughout the life history of the fish. Thus, cube law expression does not hold well throughout the life history of the fish (Srivastava, 1999). Hence, a more satisfactory formula to express the length weight relationship is $W = a L^b$. The value of 'b' in the equation usually lies

between 2.5 and 4. In an isometric growth, the value of 'b' equates 3 for a hypothetical ideal fish, if the value of 'b' is other than 3 the fish grows allometrically (Tesch, 1968).

Condition of fish in general is an expression of relative fatness of fish. The condition factor is expressed as $K = W \times 100 / L^3$. If fish does not undergo the cube law the 'K' value is directly affected by length, age, maturity, feeding intensity and other factors (Gowda, 1984). In order to eliminate the effect of these factors on the 'K' value, Le Cren (1951) suggested the calculation of relative condition factor 'Kn' by the formula $Kn = W / \hat{w}$, where W is the observed weight while \hat{w} denotes the calculated weight.

The knowledge of age and growth of an economically important fish is essential for understanding the age composition of the stocks and the role of various class- years in the fisheries. It is also essential to determine the mortality and survival rate of various year-classes and success of the yearly broods. Accordingly, knowledge of age and growth is of vital importance in the fisheries management.

6.2. Material and methods

Monthly samples were collected from Zuari estuary at Dona Paula point using a shore seine. In addition fishes were also caught by hook and lines during January 2004 - April 2005. Total length and weight of the fishes were recorded to the nearest 1.0 mm and 1.0 g, respectively.

Estimation of age and growth rate in *S. sihama* was carried out using various methods to evaluate the age at corresponding length. Petersen's length frequency polygon method and growth check on otolith were used. The growth parameters were estimated using Von Bertalanfy Growth Equation (VBGE). The condition or well-being of fish was determined by length weight relationship and calculating Relative Condition Factor.

6.2.1. Length frequency distribution (LFD)

When collecting large amount of data it is often convenient to record the data in the form of frequency table. A total number of 1178 specimens were collected during one year (2004) and arranged into size groups with 10 mm intervals. Number of specimens in each size group was recorded and the percentage of their frequency was calculated in each month, separately. Data was pooled and the frequency percentage of each size group was calculated. The frequency polygons were drawn by plotting frequency percentage against size group in different months and for pooled data.

6.2.2. Growth check on Otolith

For the study of growth the otoliths were collected from 81 specimens varying in size from 68 mm to 224 mm. Otoliths were obtained by cutting across on the dorsal sides of the head with a sharp scalpel behind the eyes. The brain with the otic capsules where the otoliths were located

became exposed in both sides. As in most fishes, *S. sihama* has three otoliths in each side. The largest otolith (sagitta) was removed from the otic capsule, washed in water, and cleaned from all extraneous tissue. The length of each otolith was measured to the nearest 0.01 mm. Then each otolith was weighed to the nearest 0.001 mg. Otoliths was then ground, immersed in 50 % glycerol and observed under binocular microscope. Reading of the annuli on the otoliths was done following the procedure given by Qasim, (1957). The relationship between total length (TL), otoliths length (OL) and weight (OW) were statistically assessed using regression analysis and calculating the correlation coefficient 'r' (Zar, 2005).

6.2.3. Growth parameters

The growth in *S. sihama* was described using the (VBGE). The equation can be written as:

$$L_t = L_{\infty} (1 - e^{-K(t-t_0)})$$

Where L_t = length at age t , L_{∞} = asymptotic length (the length of the fish would reach at an infinity age), e = base of the naporian logarithm, K = the growth coefficient (constant), t = age of fish and t_0 is the theoretical age the fish would have at length zero. There are several numbers of equations for determining these parameters, the most followed method is that developed by Ford (1933) and Walford (1946). Graphically, L_{∞} and t_0

parameters were determined by plotting the Ford - Walford graphs as described in Ricker (1975). The various parameters of VBGE were also calculated following the method given by Bal and Rao (1984). The growth rates were calculated and compared with those obtained by the LFD and checks the growth rings on otolith.

6.2.4. Length - weight relationship (LWR)

A total of 1465 specimen, 676 males and 789 females were utilized for this purpose. The length - weight relationship of male and female was calculated using the parabolic formula and its logarithmic transformation, respectively

$$W = a + L^b \text{ (Le Cren, 1951)}$$

$$\text{Log } W = \text{Log } a + b \text{ log } L$$

Where W is the weight of fish (g), L denoted the length of fish (mm), 'a' is the intercept and 'b' is the slope, 'a' and 'b' are constants. Significance of difference between the regression coefficients of sexes at 0.05 level was tested using ANCOVA (Snedecor and Cochran, 1967). Depending on the analysis, either combined or separate equation can be derived for the sexes. The 't' test was employed to test whether the regression coefficients depart significantly from expected cubic value '3' in both the sexes.

6.2.5. Relative condition factor (Kn)

The relative condition factor was calculated using the formula $Kn = W / \hat{w}$

Where W is the observed weight and \hat{w} is the calculated weight, and was calculated based on the LWR regression equation. K_n was calculated in different months for both the sexes. The average value of each month irrespective of size was considered. The average K_n for each size group was also calculated. Values of K_n were compared with Ga.S.I. and G.S.I. to infer their relation to feeding activity and maturation and spawning if there is any.

6.3. Results

6.3.1. Length frequency distribution (LFD)

The frequency distribution of different size groups in different months is given in Fig. 6.1. It showed monthly size range and modal values. It is clear from the figure that no single mode of size groups could be traced over a period of one year. Hence, attempt was made to condense the data to find the major modes. For this purpose, data was pooled and the results depicted in Fig. 6.2.

As shown in Fig. 6.2. three modes of size groups could be observed. Mode 'a' at 125 - 134 mm length, mode 'b' represented the fishes at 155 - 164 mm and the fishes belonging to size group 205 - 214 mm represented the third mode 'c'. Presence of young fishes throughout the year made it difficult to know the size at which they made their major mode.

Fig. 6.1. Bring from excel length frequency distribution

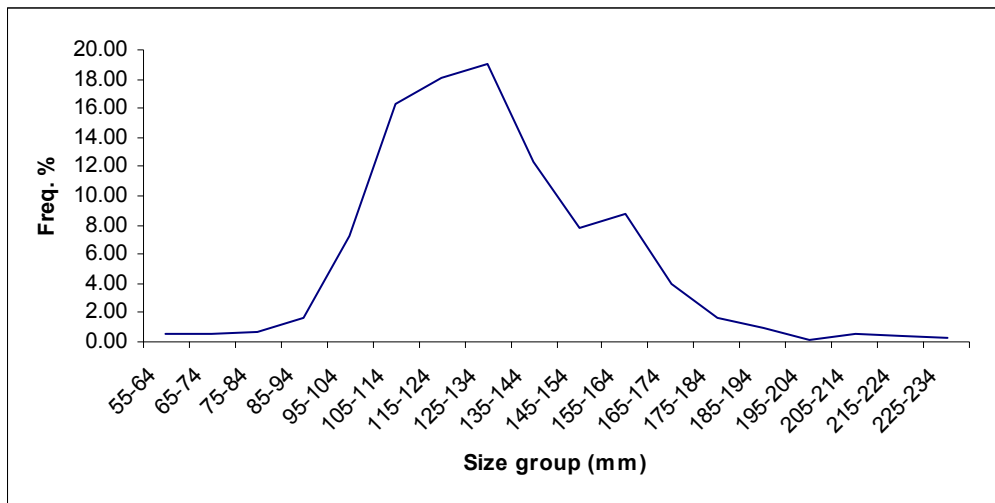


Fig. 6.2. The length frequency distribution (pooled data) during January - December 2004.

Age and growth of these main length groups could not be known directly. So, they have been assigned to different age groups based on otolith studies. The mean length at each age group is given in Table 6.1. The average lengths at various age groups obtained were in close agreement with that obtained by otolith alone. The average lengths were 86.9, 129.2, 166.9 and 202.2 mm at 0+, 1, 2, 3 years, respectively. This also suggests that population of *S. sihama* in Zuari estuary comprise of four year classes.

6.3.2. Growth check on Otolith

Since, it was not possible to determine the age from the LFD data, it was necessary to do by growth check on hard parts. As in other *Sillago spp.* the sagittal otolith of *S. sihama* were elliptical in shape, broad central region and narrow tapering end.

Generally, one-year growth ring (annulus) consists of one summer (wide and opaque) zone and one winter (narrow and translucent) zone. Plate 6.1. The mean length at various age groups e.g. 0+, 1, 2, 3 years is shown in Table 6.2. Plate 6.2 - 6.5. It was inferred that fishes with average length of 88 mm had no rings on their otoliths, while the fishes with an average total length of 130.9 mm had one clear ring on the otolith. The fishes showing two rings were found to have an average length of 168.3 mm.

Table 6.1. Mean length (mm) of *S. sihama* at various age groups.

No Of annuli on Otolith	Size Group (Mean)	Estimates Age	Designation of age group	Growth Rate
<i>None</i>	68-102 (88.0)	Less than one year old	0+	
<i>One</i>	108-145 (130.9)	One year old	1	42.9
<i>Two</i>	145- 187 (168.3)	Two years old	2	37.4
<i>Three</i>	190-224 (199.8)	Three years old	3	31.5

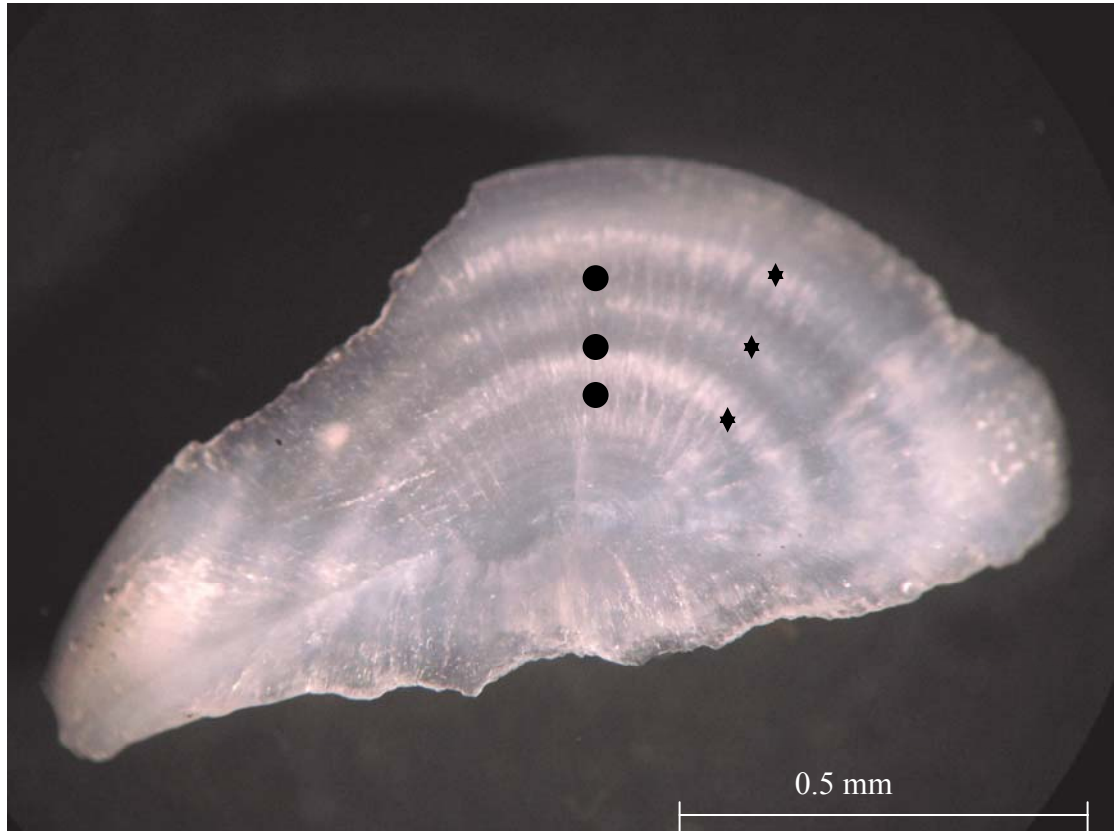


Plate 6.1. Otolith of fish belonging to 3 year group showing decrease the distance between translucent zones with the increase in age.

◆ Opaque Zone. ● Translucent Zone.

Table 6.2. Mean length at different age groups (Model progression analysis) during 2004.

Month	Model progression analysis			
	0+	1	2	3
Jan.2004	65			
Feb.		119.8		
Mar.	100	118.2		
Apr.	100.9	118.0		
May	109.7	130.1		
Jun.	91	139.7	160.7	
Jul.		140.0		
Aug.		138.9	178.4	
Sep.		129.9	160.6	194
Oct.		128.5	183	210.3
Nov.		149.8		
Dec.	55		169	
Mean	86.93	131.28	170.34	202.15
Growth rate		44.35	39.06	31.81



Plate 6.2. Otolith of fish belonging to 0 year group (total length 102 mm).

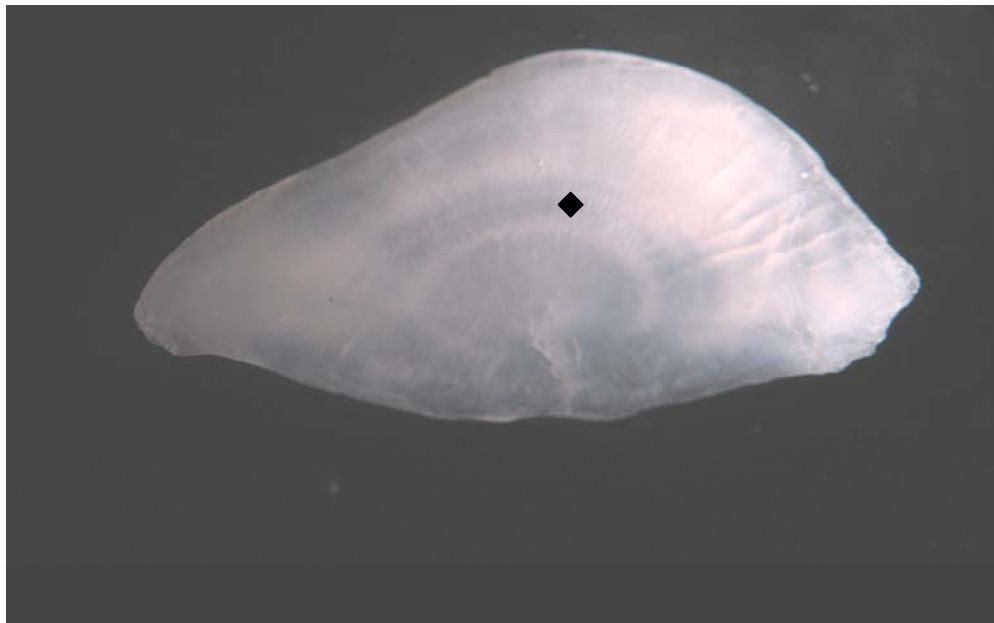


Plate 6.3. Otolith of fish belonging to 1 year group (total length 133 mm).



Plate 6.4. Otolith of fish belonging to 2 year group (total length 145 mm).

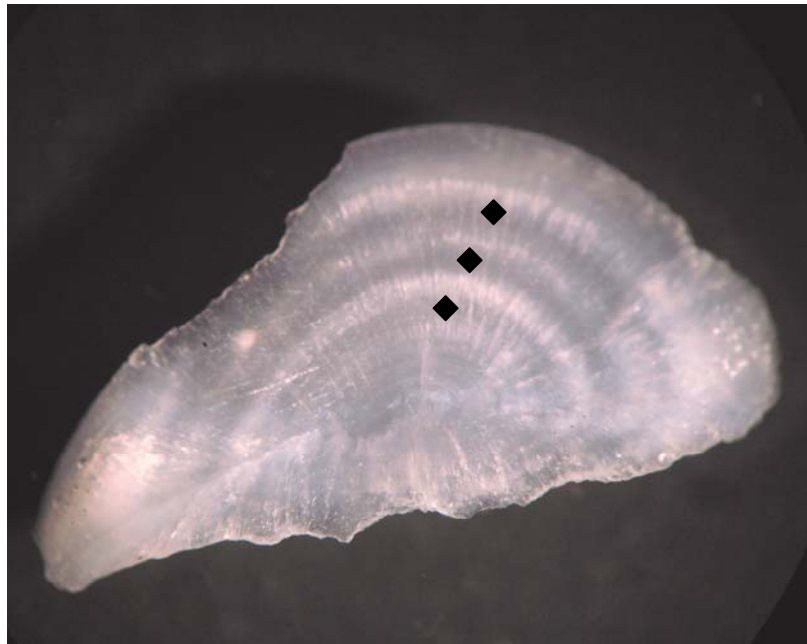


Plate 6.5. Otolith of fish belonging to 3 year group (total length 212 mm).

The mean length of fishes with three growth rings was 199.8 mm. Hence, the average length of *S. sihama* at 0+, 1, 2, 3 years was fixed as 88, 130.9, 168.3 and 199.8 mm, respectively. Split (false) annuli occurred on the age structure causing a problem in age determination is shown in plate 6.6.

The mean values of different otolith measurements in fishes belonging to various size groups are given in Table 6.3. The relationship between total length of the fish and length and weight of the otolith is illustrated in Fig. 6.3. The regression analysis based on least square method revealed that there was a highly significant association between total length of fish and length and weight of the otolith ($r = 0.94$ & 0.93 , respectively, $P < 0.001$). The regression equations were given as:

$$Y (T.L) = 1.474 + 0.0364 X (O.L)$$

$$Y (T.L) = - 0.0492 + 0.0006 X (O.W)$$

Where T.L is total length, O.L length of otolith and O.W denoted the weight of otolith.

6.3.3. Growth parameters

Growth in many fishes is widely described using the VBGE model. This model provides an adequate description of growth in many species

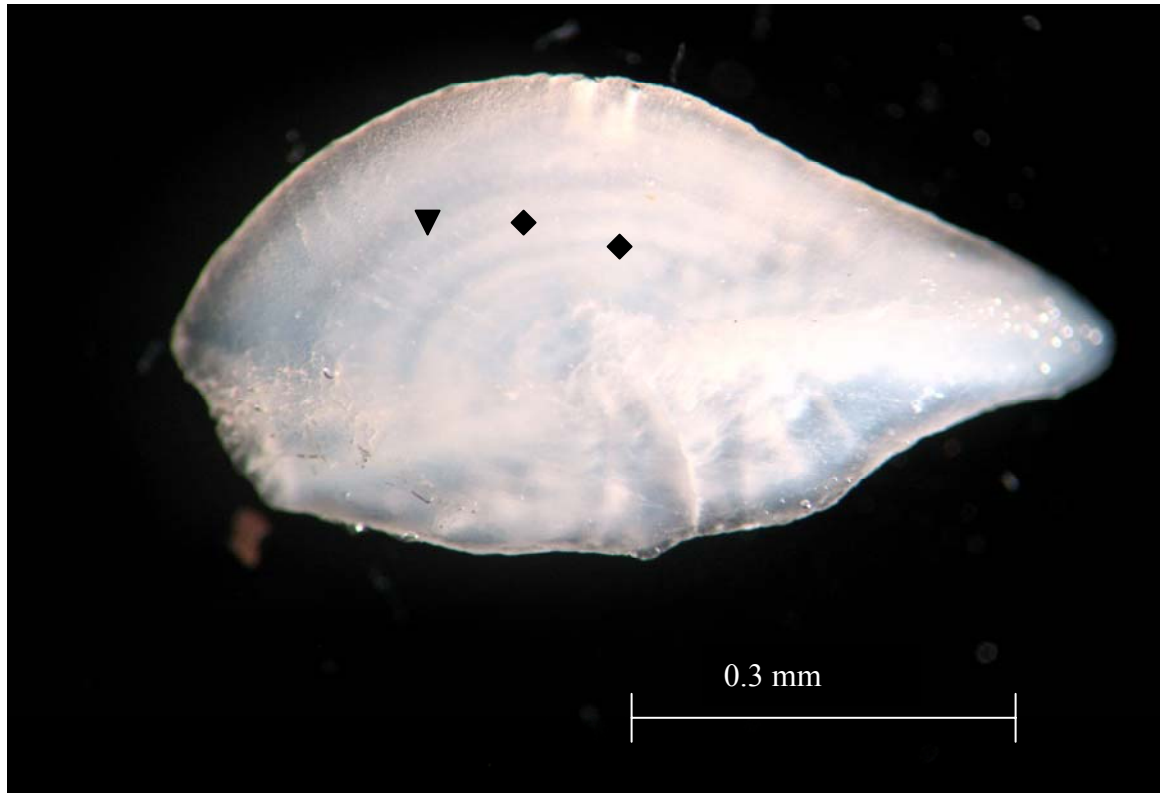


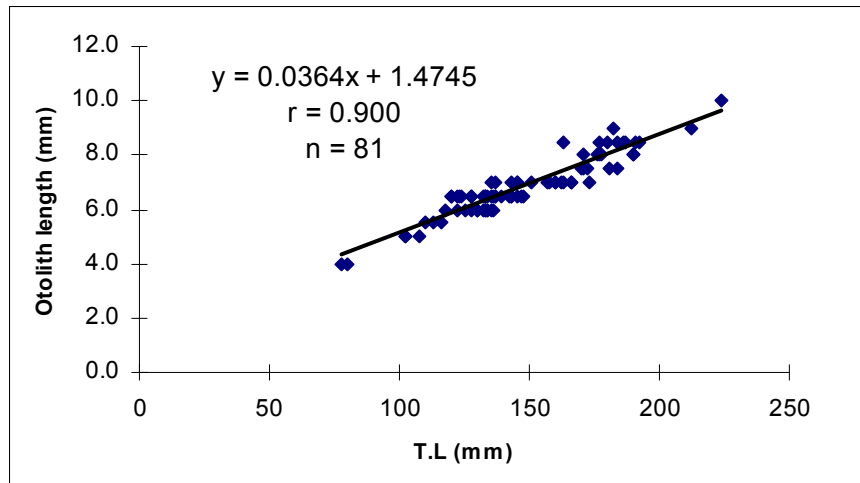
Plate 6.6. Otolith of fish belonging to 1 year group showing true and false rings.

◆ False ring. ▼ True ring.

Table 6.3. Different measurements of Otolith corresponding fish total length in *S.sihama*.

Size group (mm)	T.L Mean	O.L Mean	O.W Mean
75 - 84	79.0	4.0	0.014
85 - 94	-	-	-
95- 104	102.0	5.0	0.017
105 - 114	111.5	5.5	0.022
115 - 124	120.6	6.3	0.029
125 - 134	131.3	6.2	0.032
135 - 144	138.3	6.5	0.036
145 - 154	147.2	6.8	0.039
155 - 164	160.4	7.2	0.051
165 - 174	169.9	7.4	0.052
175 - 184	179.9	8.2	0.068
185 - 194	189.3	8.3	0.072
195 - 204	-	-	-
205 - 214	212.0	9.0	0.085
215 - 224	224.0	10.0	0.11

(a)



(b)

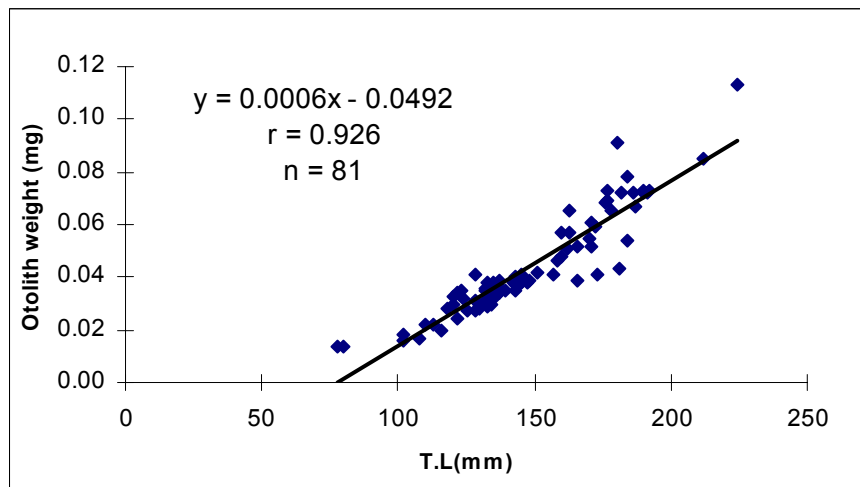


Fig. 6.3. Relationship between total length of the fish and

(a) Length of otolith

(b) Weight of otolith.

(Beverton and Holt, 1957). The growth parameters have been widely compiled and have considerable utility in life history studies. Table 6.4. showed the various parameters of VBGE. The Various parameters were found to be $L^\infty = 388$ mm and $t_0 = -1.60$ and $k = 0.1526$ /year obtained by graphical method (Fig. 6.4.) While $L^\infty = 390$ mm, $t_0 = -1.65$ and $k = 0.1537$ /year by analytical method. By substituting the above values, the VBGE for *S. sihama* can be expressed as:

$$L_t = 388 [1 - e^{-0.1526 (t - (-1.6))}] \text{ estimated by graphical method}$$

$$L_t = 390 [1 - e^{-0.1537 (t - (-1.65))}] \text{ estimated by analytical method}$$

The theoretical length at different ages as calculated by this equation showed a very close agreement with those estimated by otolith method Table 6.5. Subsequently, the growth curve of *S. sihama* is shown in Fig. 6.5.

6.3.4. Length - weight relationship (LWR)

The mathematical relationship between total length and weight of male and female obtained by logarithmic regression equations are as follows:

$$\text{Male: } \log W = - 5.1691 + 3.0045 \log L$$

$$\text{Female: } \log W = - 5.2898 + 3.0633 \log L$$

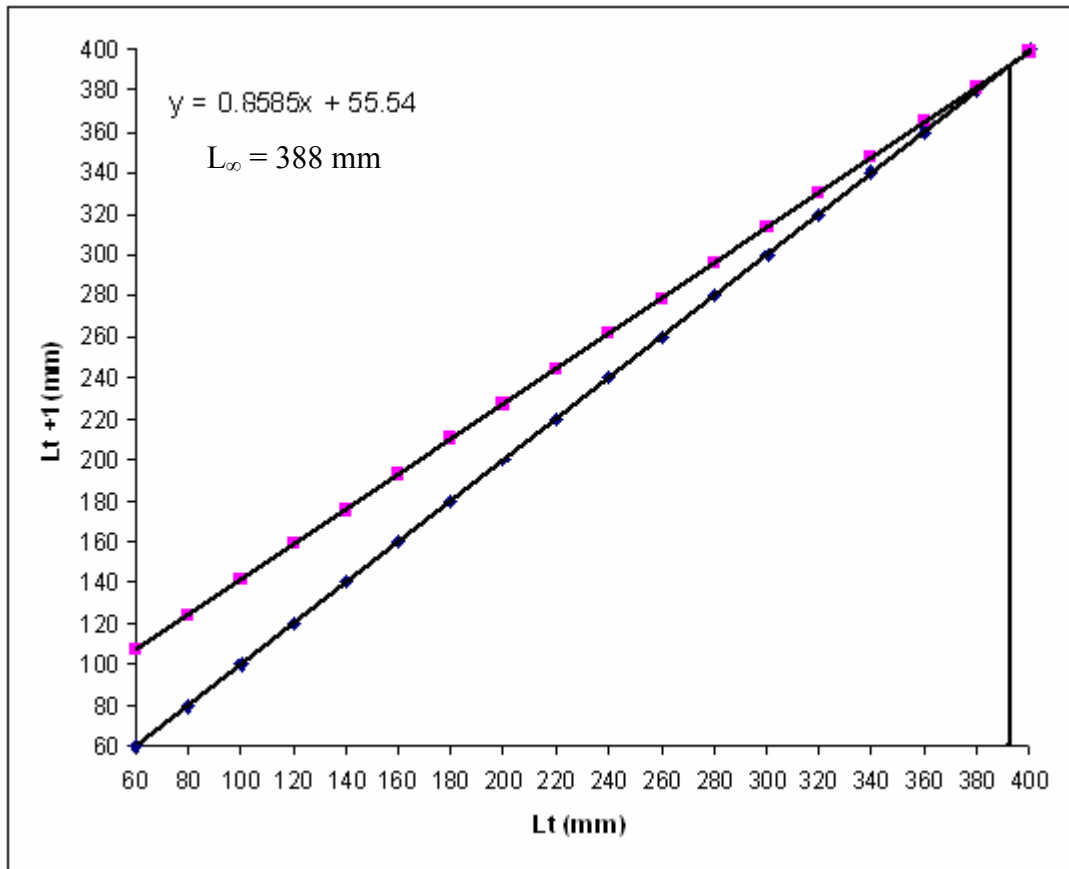
Table 6.4. Calculated length (mm) at age (year) using **VBGE** model.

Age (year)	t- t ₀	(-) K (t-t ₀)	e ^{-K(t-t₀)}	1-e ^{-K(t-t₀)}	Lt= L [∞] [1-e ^{-K(tt₀)}]
0+	1.6	-0.24416	0.7833	0.2167	84.1
1	2.6	-0.39676	0.6724	0.3276	127.1
2	3.6	-0.54936	0.5773	0.4227	164.0
3	4.6	-0.70196	0.4956	0.5044	195.7
4	5.6	-0.85456	0.4254	0.5746	222.9
5	6.6	-1.00716	0.3652	0.6348	246.3
6	7.6	-1.15976	0.31356	0.68644	266.3

Table. 6.5. Comparing the mean length of fish at various age groups using different analyses.

Age (year)	Mean length (mm)		
	L.F.D.	Otolith	VBGE
0+	86.9	88	84
1	131.3	130.9	127.1
2	170.3	168.3	164
3	202.2	199.8	195.7

(a)



(b)

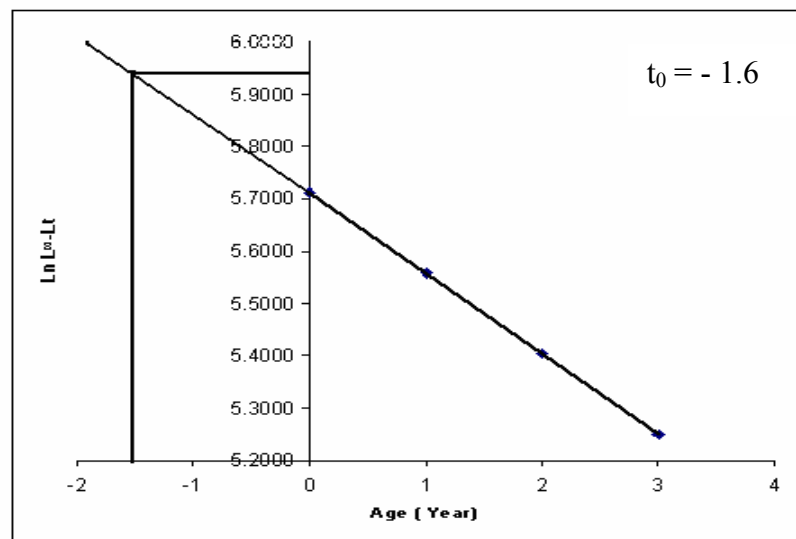


Fig. 6.4. Ford-Wal Ford Graph : (a) L_∞
(b) t_0

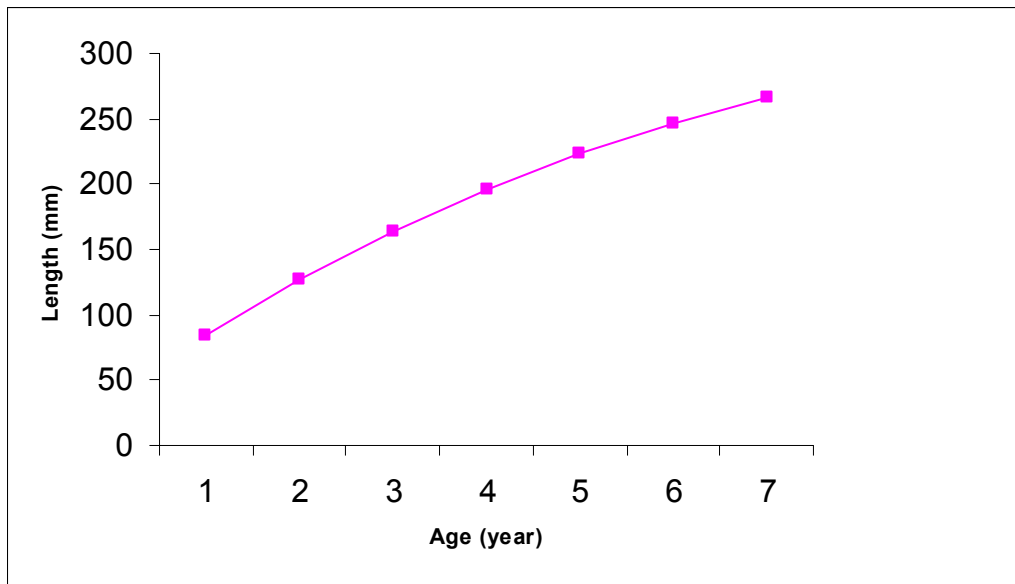


Fig. 6.5. Growth curve derived from VBGE model.

Such relationship was depicted in Fig. 6.6. and 6.7. Their corresponding parabolic equations can be expressed as:

$$\text{Male : } W = 0.00000678 L^{3.0045}$$

$$\text{Female : } W = 0.00000513 L^{3.0633}$$

The correlation coefficients 'r' were obtained from the statistical analysis as $r = 0.96$ ($P < 0.001$) in case of male and $r = 0.98$ ($P < 0.001$) in female. The results of the analysis of covariance are shown in Table 6.6. It revealed that there was no significant difference ($F = 3.31$, $P > 0.05$) in the regression coefficients between male and female. Hence, a common regression for both sexes was calculated, and the common regression equation was expressed as:

$$\text{Log } W = - 5.2462 + 3.0420 \text{ Log } L$$

And its parabolic equation is

$$W = 0.00000567 L^{3.0420}$$

The common relationship was plotted in Fig. 6.8.

Determining the variation of the regression coefficient value 'b' from '3' was tested using 't' test, the value of 't' for both the sexes were as:

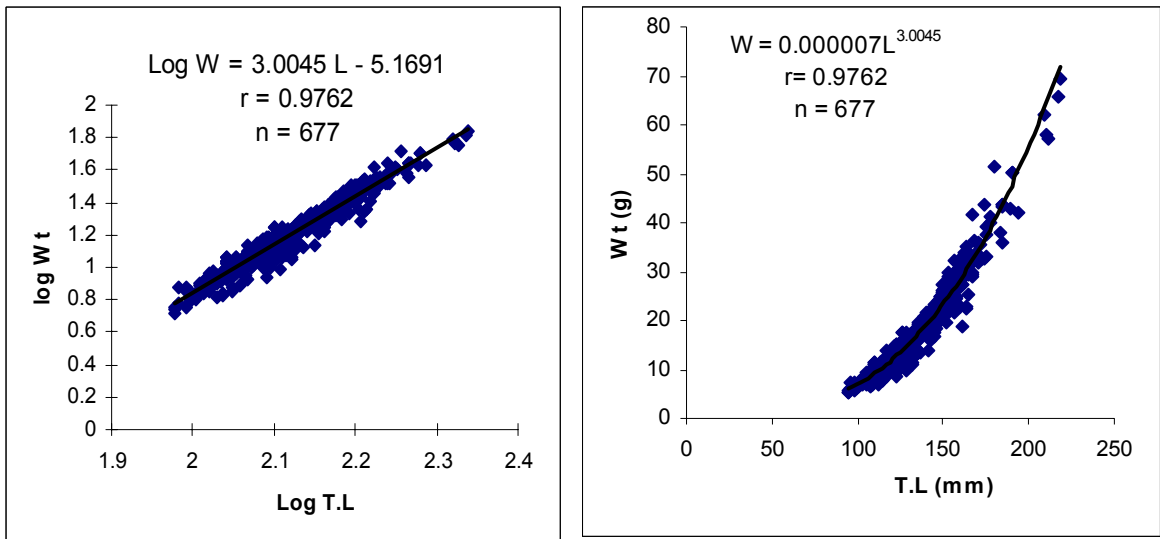


Fig. 6.6. Length – weight relationship in male *S. sihama*.

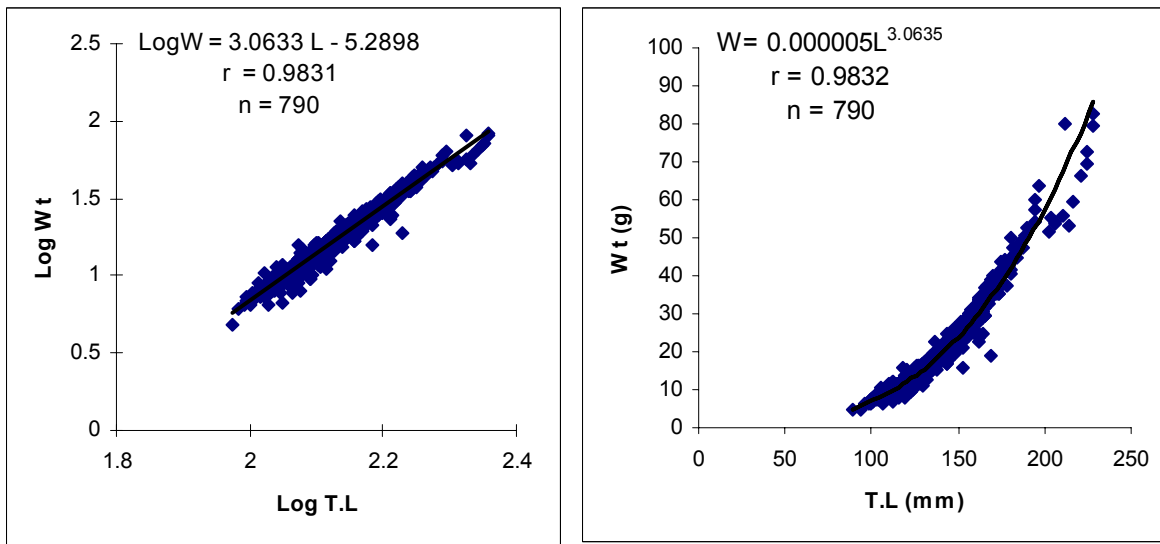


Fig. 6.7. Length – weight relationship in female *S. sihama*.

Table 6.6. Comparison of regression lines of male and female of *Sillago sihama* by ANOCOVA.

Source of variation	S x ²	S x y	S y ²	n	b	Residual	
						SS	DF
Regression (Female)	3.556961	10.8966	34.53245	790	3.06346	1.151154	788
Regression(Male)	2.62423	7.8846	24.8576	677	3.00456	1.16793	675
Pooled Regression						2.31909	1463
Common Regression	6.181192	18.7812	59.3901	1467	3.03400	2.32434	1464

F, 3.31 [0.05(1), 1, ∞] P< 0.025

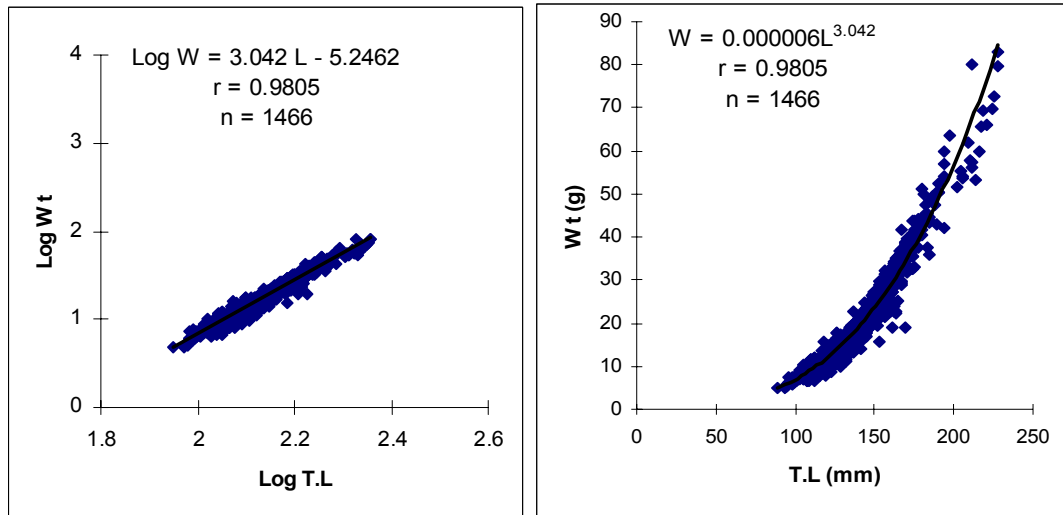


Fig. 6.8. Combined Length – weight relationship in *S. sihama*.

Male: $t_{0.01}(2), 675 = 0.18$ $P > 0.01$ not significant.

Female: $t_{0.01}(2), 788 = 3.1$ $P < 0.01$ significant.

6.3.5. Relative condition factor (Kn)

The monthly variation of Kn in male and female of *S. sihama* during February 2004 – January 2005 was shown in Fig. 6.9. and 6.10. The fluctuation showed similar trends in both sexes (Fig. 6.9.). In female Kn fluctuated between 0.90 in September to 1.07 in December. The minimum value was reported in September and the maximum in December. In male, the highest value was observed in April and the lowest in September. Generally, Kn values were high during pre-monsoon (February – May) and post-monsoon (November - January) and low during the months of monsoon (July - September) and during October.

Comparing the Kn values with G.S.I. showed that there was no direct correlation between the two variables, while the correlation between Kn values and Ga.S.I. was significant in both sexes ($r = 0.58$, $P = 0.025$) male and ($r = 0.62$, $P < 0.025$) in female. Coincidence of Kn and Ga.S.I. in male and female was depicted in Fig. 6.9. and 6.10., respectively.

The values of Kn at different size groups have been plotted separately for male and female and shown in Fig. 6.11. It showed that Kn remain

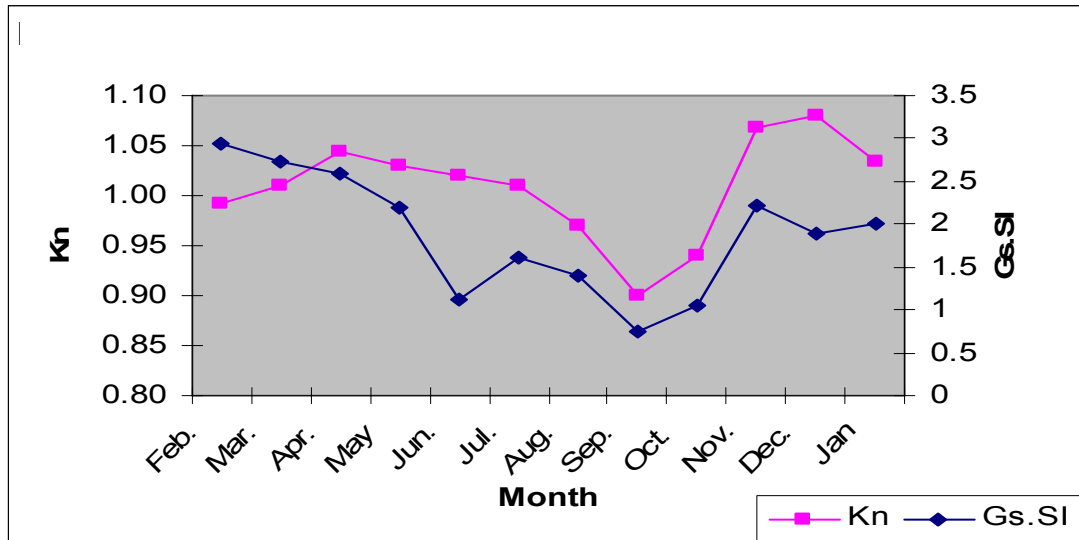


Fig. 6.9. Relative condition factor (Kn) in male *S. sihama*.

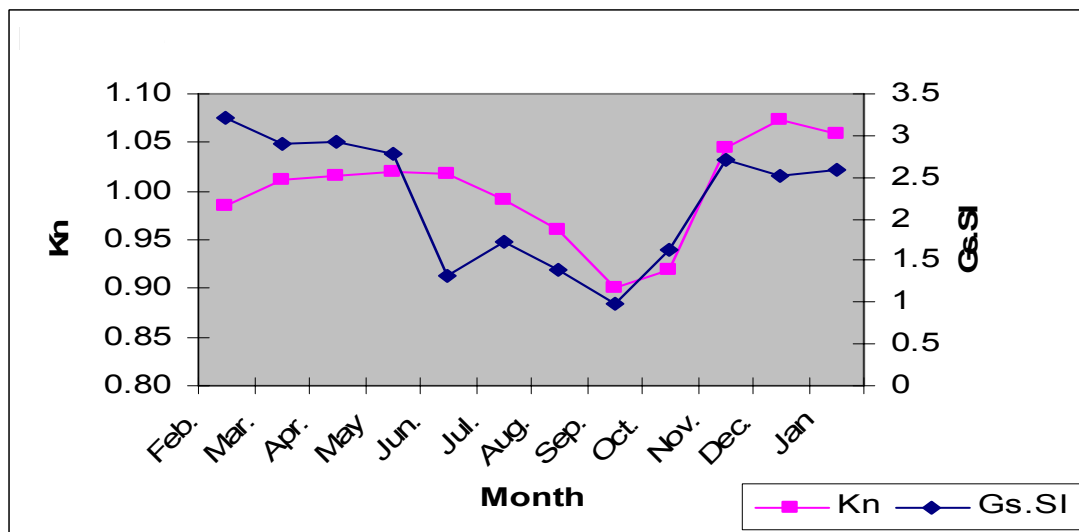


Fig. 6.10. Relative condition factor (Kn) in female *S. sihama*.

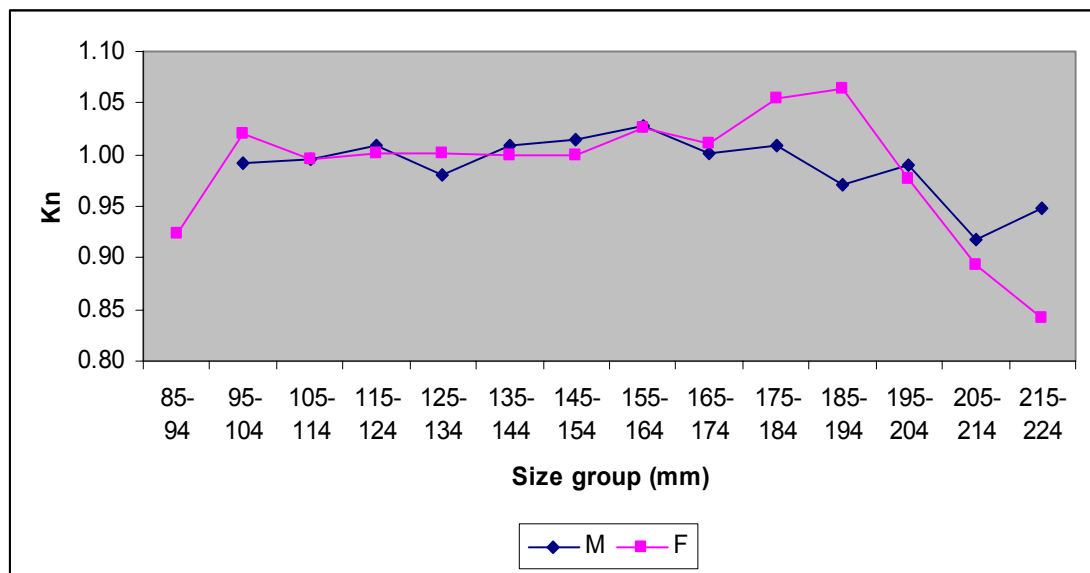


Fig. 6.11. Relative condition factor (Kn) in various size groups.

almost high and stable from size group 95 - 104 mm to 145 - 154 mm, followed by increase in 155 - 164 mm size group in both sexes. From size group 165 - 174 mm there was a gradual increase in Kn until 185 - 194 mm followed by decrease from the size group 195 - 204 mm onwards.

6.4. Discussion

6.4.1. Length frequency distribution (LFD)

As it is clear from Fig. 6.1., the modal progression could not be traced during a period of one year, so the length at age could not directly be predicted from the monthly LFD data. This difficulty in calculating the age and growth from monthly LFD of fish may be because this species has a prolonged spawning period, in which the LFD may not easily indicate the yearly broods.

In the fish that breeds at short intervals over a prolonged period and breeding is non-synchronous in the population, a study of the LFD will not give a proper indication of year classes, because of the entry of broods into the population several times in a year (Qasim, 1973). Therefore, study of LFD was carried out based on pooled data, and the results were more satisfactory. From Fig. 6.2., at least two major modes were observed at 125 - 134 mm length and 155 - 164 mm; one minor mode at 205 - 214 mm was also noticed. Hence, age may be assigned to these modes as 1, 2

and 3 year groups, respectively. Fish at 0-year group was not clearly indicated because they were caught in few numbers and that was probably due to the fishing gear selectivity in which small fishes could not be picked up.

The other attempt of studying the age and growth in *S. sihama* was a combination of LFD data and otolith annual ring count. Based on the counts of the rings on otolith, the age groups arranged as 0+, 1, 2, 3 year and the mean length at each age group was 86.9, 129.2, 166.9 and 202.2 mm, respectively. These results were more accurate than those obtained from direct LFD method. Gowda (1984) has successfully used the combined method in the study of age and growth of *S. sihama* at Mangalore. He reported the presence of four year age group in *S. sihama*, with mean length 155mm (0 year), 205 mm (1 year), 245 mm (2 years) and 275 mm (3 years). The size at different year classes disagree with the observation made in the present study. This could be attributed to variation in environmental conditions.

6.4.2. Growth check on Otolith

Determination of age and growth rate from the study of growth check was based on the assumption that the checks were annual (Qasim, 1957). The annuli are formed of alternative opaque (wide) and translucent (narrow) zones, which accumulate on the otolith. The formation of these zones in the otolith has been attributed to various factors such as seasonal

temperature, wet and dry seasons, feeding and reproductive cycles (Beckman and Wilson, 1995). Width of each opaque zone decreases with the increase in age, due to decrease in growth rate. Deviation in age patterns may results from false annuli on the otolith. These annuli tend to be discontinuous, weak and inconsistent with general growth pattern of true ones. They most occur at younger ages.

The present study indicated the presence of fish in four age groups in the population namely 0+, 1, 2 and 3 year groups based on otolith observations. The mean length for the age groups 0+, 1, 2 and 3 was arranged as 88, 130.9, 168.3 and 199.8 mm, respectively. Radhakrishnan (1957) reported the mean length at one to four year age groups as 148, 190, 224 and 240 mm. The variation in size of year classes observed by others could be related to geographical variation and prevailing environmental conditions. Krishnamurthy and Kaliyamurthy (1978) found that the estimated mean length at ages one to five were 60.2, 131.1, 185.4, 227.1 and 265.7 mm respectively. In most recent studies, David and Pancharatna (2003) reported one to four translucent zones and one to five opaque zones on the otolith of *S. indica*.

Work on age and growth of related species from different water systems in the world have been carried out. From Japanese waters, Sulistiono *et al.* (1999) reported that the longevity of specie *S. japonica* was upto 4 years. While the study of age and growth of *S. aeolus* by Rahman and Tachihara

(2005) suggested that the majority of this species die before reaching three years old. From Australian waters, sandwhiting species e.g. *S. vittata* and *S. berrus* rarely exceeded two years of age, though a small number of *S. vittata* were caught between four to seven years old (Hyndes *et al.*, 1996; Hyndes and Potter, 1997). However, the present study suggests the longevity of *S. sihama* upto three years old in Zuari estuary. The length and weight of the otolith was observed to be increased with the increase in otolith ring count. Hence, the positive correlation between total length of fish and otolith length and weight suggest that otolith ring count can be used to assess the age of this fish as reported by David and Pancharatna (2003).

6.4.3. Growth parameters

The growth parameters K and L_{∞} of the VBGE model are important in fisheries science. The K parameter is closely related to the metabolic rate of fish. A high value of K indicates a high metabolic rate and such fishes mature at early age (t_m) or at a size (L_m) which is large in relation to their asymptotic length L_{∞} (Qasim, 1973).

In the present study, the value of $L_{\infty} = 388$ mm was relatively high, and the growth coefficient $K = 0.15$ / year was almost medium. Hyndes and Potter (1997) suggested two categories of growth pattern in *Sillago spp.* from south Western Australia; the first category included fishes characterized by relatively small asymptotic length (<190 mm) and high growth

coefficient 'K' (≥ 1) whereas those in the second category attain relatively large size ($L_{\infty} > 300$ mm) and have growth coefficient $K \leq 0.5$. Accordingly, *S. sihama* from Zuari estuary fall into the second category.

Fishes belonging to the second category attain their sexual maturity at ca. 200 mm, a length reached at the end of the second year life. This is in close agreement with the present study. In *S. sihama*, as in most tropical fishes which have protracted breeding season, almost throughout the year, the entire growth is confined to the pre-maturity phase and has little growth after they become sexually mature. Krishnamurthy and Kaliyamurthy (1978) have calculated L_{∞} and K and t_0 values of VBGE in *S. sihama* from Pulicat Lake and the values are 406.82 mm, 0.2226 /year and 0.2745 year, respectively. The growth parameters reported by Gowda (1984) were 532.5 mm, 0.1548 /year and -1.066 year for L_{∞} , K and t_0 by analytical method and 510.0 mm, 0.1577 /year and -1.09 year by graphical method, respectively. The growth equation was given by Reddy (1994) as $L_t = 519.16 [1 - e^{-0.2179 (t - 0.08909)}]$ obtained by analytical method and $L_t = 508 [1 - e^{-0.211 (t - 0.05)}]$ by graphical method.

6.4.4. Length-weight relationship (LWR)

The regression coefficient of female (3.0633) was found to be higher than in male (3.0045). From this trend, it may be presumed that female gained more weight with the increase in length and subsequently age than male; this difference was not significant as it was revealed from the analysis of

covariance [$F = 3.3128, 0.05(1), 1, 1464$]. Since, there was no significant difference between slopes of regression lines in both sexes. Such result makes it necessary to combine a single regression equation to express the LWR in *S. sihama* from Zuari estuary. Gowda *et al.* (1988) reported that the regression coefficient 'b' does not differ significantly between sexes in *S. sihama* from Mangalore waters, while Jayasankar (1991) and Annappaswamy *et al.* (2004) found that the 'b' values of male and female differ significantly at 5 % level.

Although the 'b' values were almost equal to the expected value '3' for ideal fish in both the sexes. The 't' test clearly showed no departure from cube law in male of *S. sihama* from Zuari estuary. This suggests the isometric growth in male, while the growth was positive allometric in female. Although, the difference between the slopes of the regression of male and female was not significant, it reflects a difference in growth pattern in both the sexes. This difference may be attributed to gonadal development where weights of gonads of females are higher than those of males leading to gaining more weight by female. Dulcic and Karaljevic (1996) stated that the estimated parameters of length weight relationship might differ among seasons and years primarily due to physicochemical characteristics of the environment, sex and maturity stages of a given species. It has been stated that the variation of 'b' is not significant unlike 'a', which may even vary daily Goncalves *et al.* (1997).

The correlation coefficients indicate the degree of association between length and weight of the fish. The high values of correlation coefficients in both sexes revealed that there is perfect relationship between the two variables in this species.

Many workers have worked out the relationship between length and weight of *S. sihama* from Indian waters. Radhakrishnan (1957) reported the relationship between length and weight of *S. sihama* inhabiting Mandapam and Rameswaram waters as $W = 0.11504 L^{2.8862}$, the 'b' value followed the cube law. Krishnamurthy and Kaliyamurthy (1978), Gowda *et al.* (1988b) and Jayasankar (1991a) observed that the regression coefficient were not significantly different from cube law in *S. sihama* from Pulicat lake, Netravati-Gurupur Estuary and Gulf of Mannar and Palk Bay, respectively. Reddy (1993) reported the same in *S. sihama* from Kali estuary. Annappaswamy *et al.* (2004) also observed that in *S. sihama* from Mulki estuary the regression coefficient was not significantly different from '3' only in female, hence female is following the cube law. Narejo *et al.* (2003) reported a significant difference from cube law in male, female and sexes combined in spiny eel, *Mastacembalus armatus* from Bangladesh waters. From the present observations, it was concluded that the LWR followed cube law only in male of *S. sihama*. However, variation in departure of 'b' value from cube law reported by different authors may be due to difference in the number of samples used for 't' test.

While studying the LWR in *S. vincenti* from Parangipettai coastal waters Chandru *et al.* (1988) obtained a LWR equation: $\log W = -4.8282 + 2.8513 \log L$. The LWR was also estimated in other species of *Sillago*. Krishnayya (1963) working on *S. panijus* reported highly significant difference in the regression coefficients of immature and mature fishes which significantly departed from cube law. The LWR of *S. sihama* has also been estimated and reported from different water systems in the world. The 'b' values of *S. sihama* and *S. ciliata* inhabiting the coral reefs, lagoon and mangrove areas of New Caledonia were 3.13 and 3.304, respectively (Letourneur *et al.*, 1998). Harrison (2001) estimated the regression parameters of *S. sihama* as $a = 1.075 \times 10^{-5}$ and $b = 3.029$ from South African waters. Taskavak and Bilecenoglu (2001) studied the LWR of *S. sihama* along with other seventeen species from the most important species of the bottom trawl and gill net fisheries in the eastern Mediterranean coast of Turkey. In this study they found that the parabolic equation for the species *S. sihama* was expressed as $W = 0.0000014 L^{3.355}$, with high degree of correlation ($r = 0.93$).

6.4.5. Relative condition factor (Kn)

The study showed that there was a definite seasonal cycle in the Kn of both sexes of *S. sihama*. The high values of Kn during February - May maybe attributed directly to feeding activity during the summer months (Just prior to the major spawning season in *S. sihama*). Morrow (1951)

found that a peak of condition factor is reached at the start of the spawning season in long horn Sculpin, which could be associated with the pre - spawning growth of the gonads.

The gradual decline in Kn from June to October with minimum value in September coincided with the peak spawning season, may be due to decline in feeding intensity by the spawner fishes. By November - December the Kn value started increasing, coinciding with the increase in the number of the spent fishes. This may be related to the increase in the feeding intensity of the spent fishes to rebuild their body's reserves. This resulted in sharp increase of Kn at the end of spawning and during post spawning period. It has been pointed out by several authors that the condition of fishes is influenced to a varying extent by several factors. Baragi and James (1980) found it difficult to explain the changes in condition of the Sciaenid *Johneops osseus* based on the intake of food and sexual cycle. He suggested that this could depend on several other unknown factors. Seasonal variation of Kn is influenced by the gonadal development, feeding activity and several other factors (Gowda, 1984; Doddamani *et al.*, 2001)

In the present investigation, comparing monthly variation of Kn with Gastro and Gonado somatic indices revealed a significant correlation between Kn and Gastro somatic index in both the sexes. This suggests that feeding intensity may be the main but not the only factor responsible for the

monthly variation in Kn in *S. sihama*. It seems that there is an interrelation between feeding intensity and reproduction and these two factors are the most important that influence the Kn. These findings corroborate observations by Qasim (1957) in *Centronotus gunnellus* and Das (1978) in *Mugil cephalus*.

In relation to size, the fishes of the size groups 95 - 104 to 145 - 154 mm comprised mostly of immature and maturing have high Kn values. This is expected because of high feeding intensity in these size groups. The first sharp increase of Kn at 155 - 164 mm length in both sexes may reflect the length at first maturity. The gradual rise in Kn values from group 165 - 174 mm to group 185 - 194 mm followed by decrease in larger fishes due probably to the gain in weight of recovering fishes. The increase in Kn values after the size group 165 - 174 mm is more rapid in female than in male, thus indicating the possibility of the fact that recovery after spawning has more marked effect on Kn of the female than male fish. David and Pancharatna (2003) studied K and Kn in *S indica*. They reported that the gradual decrease in the fish condition after the size at first maturity may be due to decline in feeding activity in response to commencement of spawning period. They also reported decrease in K and Kn with the increase in length and age suggesting that juveniles have a better condition factor than adults.

The above observations revealed that the population of *S. sihama* from Zuari estuary comprising of four year groups. The mean length at different year groups estimated by LFD and using VBGE are in close agreement with those estimated by count rings on otolith indicating the validity of otolith in age determination in tropical fishes. *S. sihama* in this area following an isometric growth pattern in male only. Feeding activity and reproduction cycle are the main factors influence the condition of the species.