Egyptian Journal of Aquatic Biology and Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(6): 727 – 758 (2024)
www.ejabf.journals.ekb.eg

Fishery Biology of *Sillago muktijoddhai* Collected from Cox's Bazar Coast, the Bay of Bengal, Bangladesh

Md. Azharul Islam Palash[1], Prianka Kundu[1], Anirban Sarker[1], Subrina Sehrin[1], Tianxiang Gao[3], Mohammad Abdul Baki[1, 2], Shilpi Saha[1]*

[1]Department of Zoology, Jagannath University, Dhaka 1100, Bangladesh
[2]Noakhali science and Technology University, Noakhali 3814, Bangladesh
[3]Fishery College, Zhejiang Ocean University, Zhoushan 316022, China
***Corresponding Author: shilpisahazoo@gmail.com**

ARTICLE INFO

Article History:
Received: July 15, 2024
Accepted: Aug. 21, 2024
Online: Nov. 27, 2024

Keywords:
Sillaginidae,
Sillago muktijoddhai,
Reproductive biology,
Length-weight relationship,
Food and feeding habits,
Cox's Bazar coast

ABSTRACT

Sillago muktijoddhai is a marine fish found along the Bay of Bengal in Bangladesh and the coast of India. However, detailed information on its reproductive biology, length-weight relationship, and feeding habits is lacking. To fill this gap in literature, a research was conducted from August 2022 to October 2023, during which 444 individuals were collected from the Cox's Bazar coast of the Bay of Bengal, Bangladesh. The total length and weight of the fish ranged from 51.23 to 200.5mm and 2.47 to 71.73g, respectively. Analysis of the sex ratio revealed a dominance of males over females, with a ratio of 1.36:1 (X^2 = 10.41, $P< 0.05$). The condition factors indicated that males exhibited a better growth pattern than females. The gonadosomatic index suggested that the peak breeding season occurs in November. Histological observations identified four distinct stages of gonadal development for males: immature, maturing, ripe, and spent. For females, the stages were immature, maturing, mature, and ripe. The absolute fecundity ranged from 6,164 to 30,555 eggs per ovary, with a mean value of 12,176 ± 1,050. The regression coefficient (b) for the length-weight relationship was 3.213, indicating a positive allometric growth pattern. Morphometric analysis of the mouth and relative gut length revealed that *S. muktijoddhai* is a bottom feeder with carnivorous habits. Gut content analysis showed that crustaceans formed the major component of its diet, although zooplankton, gastropods, bivalves, and sand were also present.

INTRODUCTION

The family Sillaginidae, Richardson (1846), commonly known as sand whiting or sand borer, primarily inhabits inshore water with a sandy substrate or estuarine areas of rivers throughout the Indo-West Pacific region **(McKay, 1985; McKay, 1992; Johnson, 1993; Nelson, 2016)**. Currently, the family has 41 described species **(Greenwood *et al*., 1966; McKay, 1992; Kaga *et al*., 2010; Gao *et al*., 2011; Golani *et al*., 2013; Nelson *et al*., 2016; Xiao *et al*., 2016a; Panhwar *et al*., 2017; Divya *et al*., 2021; Xiao *et al*., 2021; Saha *et al*., 2022, 2024; Yu *et al*., 2022)** belonging 3 genera, *Sillago* (Cuviar, 1817); *Sillaginopsis* (Gill, 1861), and *Sillaginodes* (Gill, 1862). **Saha *et al*. (2022)** recently discovered *Sillago muktijoddhai* from the Bay of Bengal of Bangladesh part. However, five Sillaginids, namely *Sillago muktijoddhai, S. mengjialensis, S. sihama, S. soringa,* and *Sillaginopsis domina* are found along the coastal regions of Bangladesh **(Saha *et al*., 2022)**. Among them, *Sillago muktijoddhai* **(Gao & Saha, 2022)** is an inshore marine and estuarine fish species found along the coastal regions of the Bay of Bengal, Bangladesh, and the eastern coast of India **(Saha *et al*., 2022)** and has considerable commercial importance. It is locally called ‘Sagorer Baila’ or Choto Tular Dati and was previously misidentified as the *S. sihama* in Bangladesh **(Saha *et al*., 2022)**. Reproduction is a physiological process that is crucial in the life cycle of living organisms including fish **(Muchlisin, 2013)**. A full understanding of reproductive biology is important in fisheries research, stock assessment, stock discrimination, and for providing sound scientific advice in fishery management **(Offem *et al*., 2008; Tsikliras *et al*., 2013; Hossain *et al*., 2017; Khatun *et al*., 2019)**. In fisheries science, the sex ratio is important in estimating stock size and reproductive potential **(King, 1995; Vazzoler, 1996)**. However, studies on sex ratio reveal segregation or aggregation of males and females in accordance with environmental conditions **(Khan & Hoda, 1993)**. The condition factor (K) is used to compare the "condition", i.e., the fatness or well-being of fish **(Seher & Suleyman, 2012)**. Gonadosomatic index (GSI) has been routinely utilized to assess the time of reproduction **(Lowerre-Barbieri *et al*., 2011)**. The GSI is widely utilized to compare individual reproductive status with that of other groups of individuals **(Flores *et al*., 2019)**. Histology of gonads offers a powerful tool for reproductive studies and is routinely used for sex verification, assessment of the reproductive phase, or quantification of atresia **(Blazer, 2002)**. Fecundity in itself is generally described as the number of mature oocytes (ripening eggs) found in the female just before or during spawning **(DeMartini & Sikkel, 2006; Ganias *et al*., 2014)**. Ideally, fecundity increases with an increase in the size of fish **(Bagenal, 1978)**, hence data on fecundity can be used to understand fish survival, populations or stocks, and hatchery estimations **(Lasker, 1985)**. In addition, the reproductive biology of closely related species to *S. muktijoddhai* has been studied by several authors. Research on *Sillago sihama* includes work by **Sahafi *et al.* (2001)**, **Shamsan and Ansari (2009)**, **Khan *et al.* (2013)**, and **Sawant *et al.* (2015)**. Studies on *Sillago maculata*, *Sillago bassensis, Sillago japonica*, and *Sillaginodes punctata* have been conducted by **Hyndes and Potter (1995, 1996)**, **Sulistiono *et al.* (1999)**, **Kendall and Gray (2009)**, and **Manjappa *et al.* (2015)**, respectively.

Furthermore, the length-weight relationships (LWRs) of fishes are important in the ecology of fishes **(Froes, 2006)** and fisheries and biology **(Sarkar *et al*., 2008)**. Several researches on the length-weight relationship over different periods were conducted by countless researchers, such as **Jayasankar (1991)**, **Mirzaei *et al*. (2013)**, **Innal *et al*. (2015)**, **Khan *et al*. (2015)**, **Alavi-Yeganeh *et al*. (2016)**, **Pramanik and Mohanty (2016)** and **Pradhan *et al*. (2020)**. Feeding ecology is an important aspect of understanding the functional role of the fish within their ecosystems **(Blaber, 1997; Cruze Escalona *et al*., 2000; Hajisamae *et al*., 2003; Abdel-aziz & Gharib, 2007)**. However, knowledge of the food requirements, feeding behavior patterns, and predator-prey relationships helps understand the predicted changes that might result from any natural or anthropogenic intervention **(Hajisamae *et al*., 2006)**. In addition, study on the food and feeding habits of *Sillago sihama* (Frosskal, 1775) was conducted in different locations by several researchers, viz. **Gunn and Milward (1985)**, **Taghavi- Motlagh *et al*. (2012)** and **Khan *et al*. (2014)**.

No study has been conducted on the reproductive biology of *Sillago muktijoddhai* yet. Moreover, there is no available study on the length-weight relationship and food and feeding habits of this newly discovered species. The lack of research enforced us to conduct the current study. The result of this study may be very helpful in fishery management, biodiversity maintenance, and conservation aspects of this species.

MATERIALS AND METHODS

Sample collection

Sampling was monthly conducted from August 2022 to October 2023 covering three local markets: Kolatoli Bazar, Baharchara Bazar, and Kanaiya Bazar in Cox's Bazar, Bangladesh (Fig. 1). Additionally, samples were collected from local fishermen who caught this fish species using beach seines, excluding the fishing ban period and times when the fish were not available in the study area. After collection, photographs were taken, and the samples were transported to the Fisheries Lab at the Department of Zoology, Jagannath University, for further investigation. Some fish were preserved as voucher specimens in the fisheries lab, with the following identification numbers: CO822-01, 02, 31, 37, 47, 89, and 91.

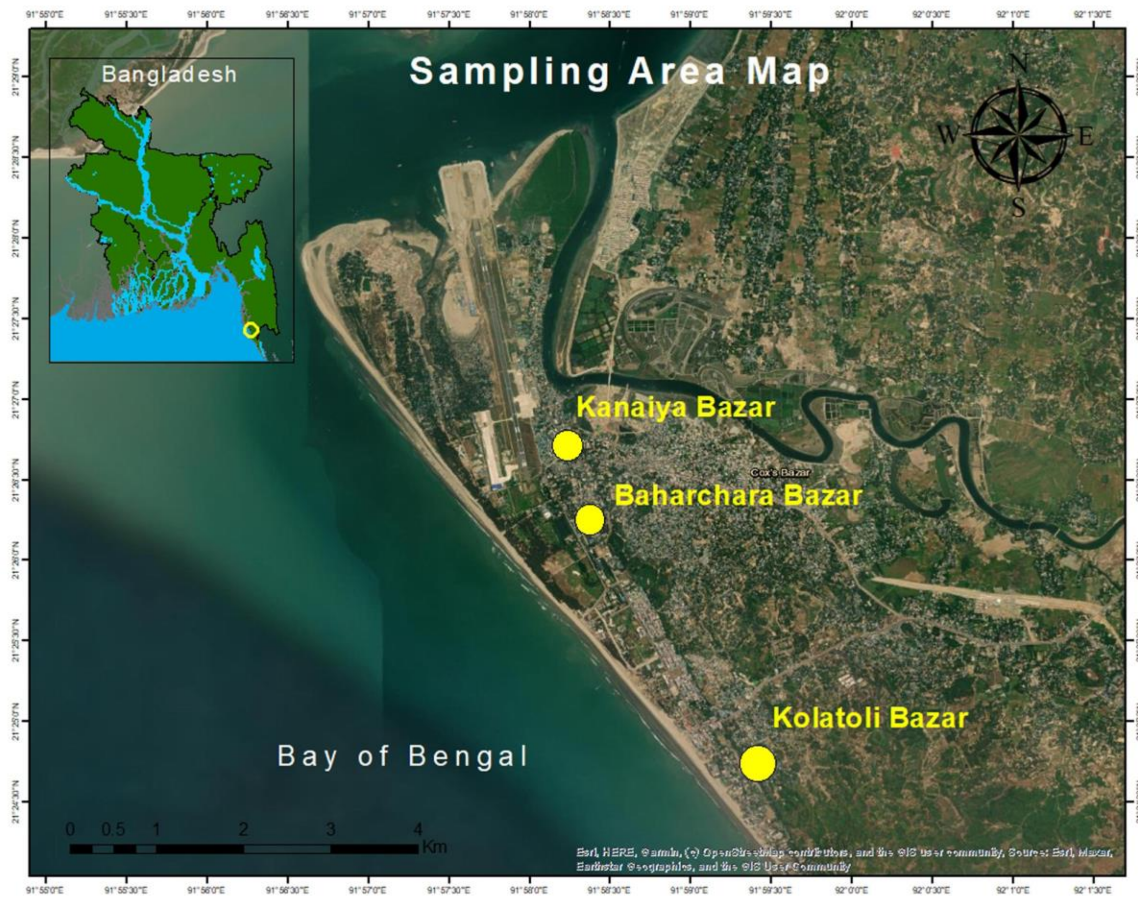

Fig. 1. Sampling area (Kolatoli Bazar, Baharchara Bazar and Kanaiya Bazar)

Fish identification

All counts and measurements followed the **Hubbs and Lagler (1947)** methods. All measurements were taken with slide calipers to 0.1mm. The weight of the fish was taken to the nearest 0.01gm by a digital weight machine. The terminology of appendages of swim bladder followed **Shao *et al*. (1986)** and **Kaga and Ho (2012)**. However, the specimens were identified properly according to **McKay (1992)** and **Saha *et al.* (2022, 2024)**.

Morphological identification

Initially, the fish were identified based on their external features, such as body coloration, the presence of black dots lying below the lateral line, and the intensity of small dark spots on the anal fin. Then, the identification was confirmed by investigating the most distinguishing feature of the fish: the swim bladder.

Molecular identification

DNA extraction: Epaxial white muscle tissue was collected from five fresh specimens of *S. muktijoddhai* and preserved in 95% ethanol under -20℃. Genomic DNA was extracted by proteinase K digestion followed by a standard phenol-chloroform method **(Sambrook *et al*., 1989)**.

PCR amplification and sequencing: Cytochrome oxidase subunit I (COI) was amplified to analyze genetic differences among Sillaginids. In light of **Saha *et al*. (2022, 2024)**, the primer, FishF1: 5′-TCAACCAACCACAAAGACATTGGCAC-3′ and FishR1: 5′-TAGACTTCTGGGTGGCCAAAGAATCA-3′ were designed to identify genetic differences of the studied species from closely related species **(Ward *et al*., 2005)**. The PCR reaction system consisted of 25μL, which included 1μL of template DNA, 2.5μL of 10× PCR buffer, 1.5mmol/L $MgCl_2$, 200μmol/L dNTPs, 0.2mmol/L of each primer, and 1.25 units of Taq DNA polymerase. The reaction conditions were as follows: pre-denaturation at 94°C for 5 minutes; denaturation at 94°C for 45 seconds; annealing at 50°C for 45 seconds; extension at 72°C for 45 seconds; and a total of 35 cycles, followed by a final extension at 72°C for 10 minutes.

The PCR products were separated on 1.5% agarose gel and purified using the BioDev Gel Extraction System B (BioDev Technology, Beijing, China). The cleaned products were sequenced using a BigDye Terminator Cycle Sequencing Kit v2.0 (Applied Biosystems, Foster City, CA, USA), with sequencing performed on an ABI Prism 3730 automatic sequencer (Applied Biosystems), utilizing both forward and reverse primers for amplification.

Sequence analysis: Lasergene software (Lasergene, Madison, WI, USA) was used for sequence comparison. Clustal X 2.1 **(Larkin *et al*., 2007)** was used to align the sequences.

Sequence blasting: Sequences were blasted on the NCBI website (NCBI, http://www.ncbi.nlm.nih.gov/nucleotide) to check the similarity with reference sequences.

Sex ratio

The sex of the fish was confirmed by checking the gonadal status of the individuals. A chi-square test was performed to test their equality in distribution.

Condition factor

The condition factor was calculated by using the following equation-

$$K=100W/L^3$$ **(Pauly, 1983)**

Where, K= Condition factor, W= Mean body weight (gm), and L= Mean total length (mm).

Estimation of gonadosomatic index

The GSI was determined by using the following formula-

$$GSI= (Gonadal\ weight/Total\ weight) \times 100$$ **(King, 1995)**

Histology of gonads

Gonads at various developmental stages (immature, maturing, mature, ripe, and spent) were collected from individual fish and fixed in 10% buffered formalin. The targeted portions of the fixed gonads were processed following standard protocol 23 and embedded in paraffin wax. The paraffin blocks were then sliced into 5-µm thick sections using a rotary microtome. These sections were stained with the Ehrlich hematoxylin-eosin sequence as described by **Gray (1964)**. The stained gonadal sections were examined under an electronic microscope (Nikon Eclipse 200) at 100x magnification and photographed for documentation and analysis.

Fecundity

To estimate the number of eggs in the ovaries, the Gravimetric method was used. Initially, the ovaries were rinsed with water and placed in Gilson's fluid to dissolve the connective tissues. Then, three sub-samples were taken from the anterior, middle, and posterior parts of the ovary. Finally, the samples were weighed and the average number of eggs in each subsample was counted directly, the mean value would be considered with the equation given below:

$$F = n \times G/g$$ **(Bagenal, 1978)**

Where, F = Absolute fecundity, n = Average number of eggs in each subsample, g = Subsample weight (g), G = Ovarian dry weight (g).

Relative fecundity was calculated by the following equation:

$$R = F/TW$$ **(Bagenal, 1978)**

Where, R= Relative fecundity, F= Absolute fecundity, TW= Total body weight (g)

Length-weight relationship

Length-weight relationship was determined by fitting the data to a potential relationship based on the exponential equation **(Le Cren, 1951)** in the form of $BW = aTL^b$, where BW is the body weight (expressed in g); TL is the total length (expressed in mm); a is a coefficient related to body form; and b is an exponent indicating isometric growth when b is equal to 3, while indicating allometric growth being significantly different from 3 **(Simon & Mazlan, 2008)**. The parameters 'a' and 'b' of the exponential curve were estimated by linear regression analysis over log-transformed data expressed as $\log BW = \log a + b \log TL$. The values of the constant 'a' and 'b' of the linear regression were determined by following the methods of **Rounsefell and Everhart (1953)** and **Lagler (1966)**.

Food and feeding habits

Feeding habits: Feeding habits were assessed by investigating the external features, such as mouth position, mouth type, mouth gape, mouth shape, jaw condition, lip condition, teeth condition, etc. The feeding habits of the fish were also determined by using the relationship of the relative length of the gut (RLG), where RLG > 3 represents herbivore; RLG < 1, carnivore; and 1-3 RLG value represents omnivore **(Odum, 1970)**.

The relative length of the gut was determined by the following method:

The relative length of gut (RLG) = Length of gut/ length of the total body

Food content analysis: The stomach was dissected out, and fixed in 5% formalin. The gut contents were analyzed using quantitative and qualitative methods **(Hynes, 1950; Natarajan & Jhingran, 1961)**.

Statistical analysis

All statistical analyses were performed using Microsoft Excel, and results were presented as mean ± standard deviation (Std.).

RESULTS

1. Fish identification

1.1 Morphological identification

The fish had an elongated body and greenish appearance on the dorsal side (Fig. 2). XI spines were present in the first dorsal fin; the second dorsal fin had I spine and 20-21 soft rays. The anal fin had several minute black dots. Underneath the lateral line, black dots in clustered form were also evident. A broad swim bladder, with two anterior extensions as well as two posterior extensions, was observed (Fig. 2). A lacuna at the base was also evident. 8-10 lateral processes were present on either side of swim bladder.

1.2 Molecular identification

Total five specimens were barcoded (voucher no. CO822-02, 37, 80, 89, 91) for molecular identification. The BLAST result of DNA sequences in the NCBI showed 98.89-99.68% similarity with reference sequences of *S. muktijoddhai* submitted by **Saha *et al*. (2022)**. Sequences of this study are available in GenBank under the accession numbers PQ219311-PQ219315.

2. Morphometric study and size-based frequency

Some morphometric aspects of *S. muktijoddhai* were observed which are shown in Table (1).

An analysis of size-based (Total length) frequency was done to determine whether the males or females were abundant in large size group throughout the study periods. The results indicated that the females of *S. muktijoddhai* were dominant in large size group in all the sampling months, while in March the males were dominant.

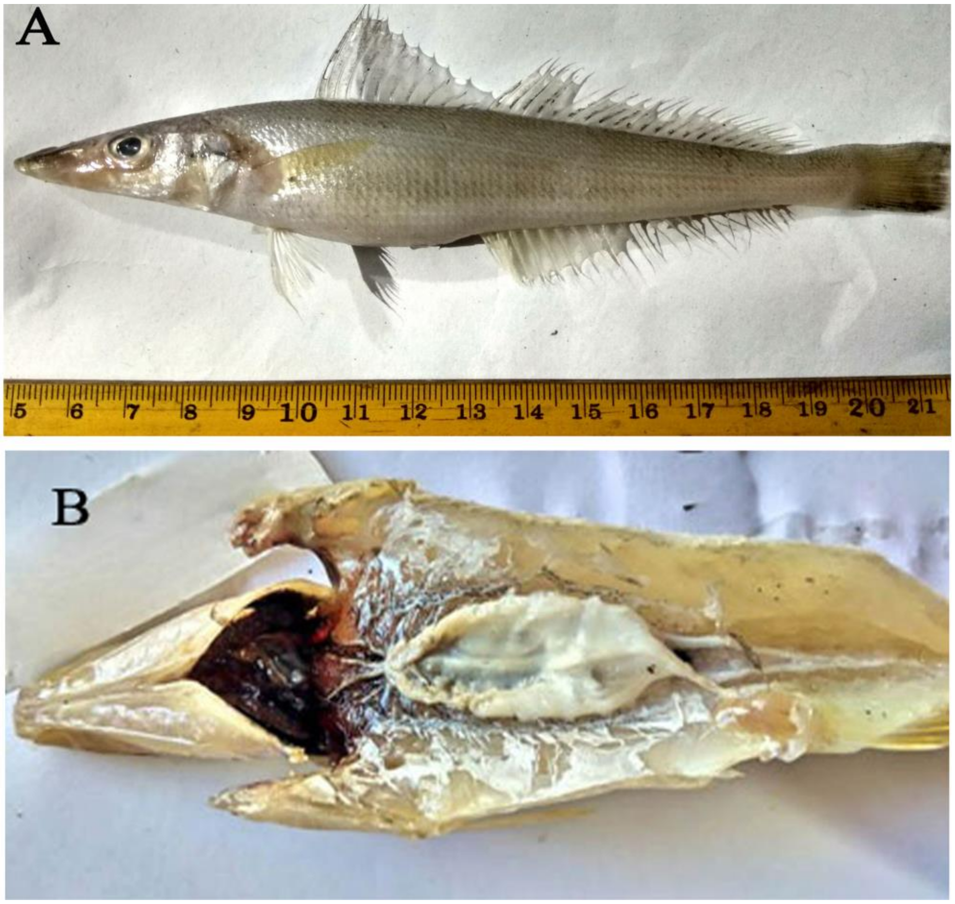

Fig. 2. A. Morphology of *S. muktijoddhai* (165.17mm TL); **B.** Swim bladder of *S. muktijoddhai*

3. Breeding biology

3.1 Sex ratio

A total of 444 fish samples were investigated during the study period. The overall percentages of females and males were 42.34 and 57.66%, respectively. The monthly ratio of males and females ranged from 1.13:1 to 1.54:1 (Table 1). The overall sex ratio was 1.36:1 (X^2 = 10.41, P< 0.05) which showed that the proportion of male and female population differ significantly

3.2 Condition factor

For the values of condition factor, K for both males and females are represented in Table (1). The mean K-value for *S. muktijoddhai* for the total sampling period was found to be 1.008 ± 0.002 for females, and 1.012 ± 0.003 for males. The males showed a better condition factor of growth pattern than females in August-December except in March.

3.3 Gonadosomatic index

The GSI was calculated for each individual and clustered into sex as well. The male showed a higher GSI value during the months of March and November, while the female had a higher GSI value for March, August, and November (Table 1). Therefore, the results showed that the peak spawning season of *S. muktijoddhai* was in November.

Table 1. Descriptive results of morphometric measurements, monthly sex ratio, condition factor and GSI of *Sillago muktijoddhai*

		Morphometric measurements				Sex ratio				Condition factor			GSI
Month	Sex	Total length (mm) (mean±std.)	Body weight (gm) (mean±std.)	Gonad length (mm) (mean±std.)	Gonad weight (gm) (mean±std.)	Percentage	Ratio (M:F)	Chi-Square (X^2)	*P*-value	K- value (Mean±St. error)	Upper Cl (95%)	Lower Cl (95%)	Mean±Std.
August, 2022	M	164.62 ± 8.92	33.19 ± 4.78	18.66 ± 3.69	0.28 ± 0.18	55.88	1.27:1	1.88	0.17	1.009 ± 0.01	1.03	0.988	0.695 ± 0.585
	F	170.51 ± 7.79	37.56 ± 5.83	20.24 ± 4.35	0.43 ± 0.53	44.12				1.005 ± 0.012	1.029	0.98	1.259 ± 1.643
November, 2022	M	116.1 ± 30.94	13.4 ± 9.82	20.93 ± 9.91	0.67 ± 0.61	53.00	1.13:1	0.36	0.55	1.006 ± 0.012	1.03	0.981	3.195 ± 2.522
	F	133.78 ± 30.4	19.4 ± 11.14	25.18 ± 11.01	0.77 ± 0.60	47.00				1.003 ± 0.013	1.029	0.976	3.933 ± 3.085
March, 2023	M	146.52 ± 11.74	24.41 ± 6.48	24.52 ± 6.31	0.25 ± 0.21	57.14	1.33:1	1	0.32	1.004 ± 0.017	1.040	0.968	1.175 ± 1.184
	F	138.95 ± 13.31	19.29 ± 5.88	21 ± 8.79	0.43 ± 0.39	42.86				1.014 ± 0.035	1.089	0.938	2.629 ± 2.527
September, 2023	M	174.33 ± 8.55	44.12 ± 14.69	31.66 ± 19.29	0.11 ± 0.15	60.64	1.54:1	4.26	0.04	1.023 ± 0.042	1.003	0.962	0.243 ± 0.352
	F	178.39 ± 12.02	47.61 ± 10.53	30.28 ± 6.02	0.33 ± 0.17	39.36				1.004 ± 0.014	1.032	0.976	0.711 ± 0.341
October, 2023	M	169.94 ± 19.2	43.23 ± 5.83	27.87 ± 7.57	0.06 ± 0.05	54.00	1.17:1	0.38	0.54	1.009 ± 0.023	1.048	0.955	0.139 ± 0.123
	F	175.31 ± 9.46	46.39 ± 7.98	31.12 ± 5.89	0.42 ± 0.39	46.00				1.004 ± 0.016	1.037	0.97	0.893 ± 0.785
Total	M	154.34 ± 21.31	31.67 ± 11.63	24.73 ± 4.67	0.22 ± 0.12	57.66	1.36:1	10.41	0.001	1.012 ± 0.003	1.019	1.001	
	F	159.39 ± 19.03	34.06 ± 12.49	25.57 ± 4.53	0.44 ± 0.08	42.34				1.008 ± 0.002	1.011	0.102	

M- Male; F- female; Std.- Standard deviation; K- Condition factor; CI- Condition interval

3.4 Histology of gonad

The morphological and histological studies of the gonads revealed four developmental stages for both males (immature, maturing, ripe, and spent; Figs.3 i-iv) and females (immature, maturing, mature, and ripe; Fig. 4). These developmental stages were observed through both macroscopic and histological examination and were compared with those of *S. sihama* (Table 2).

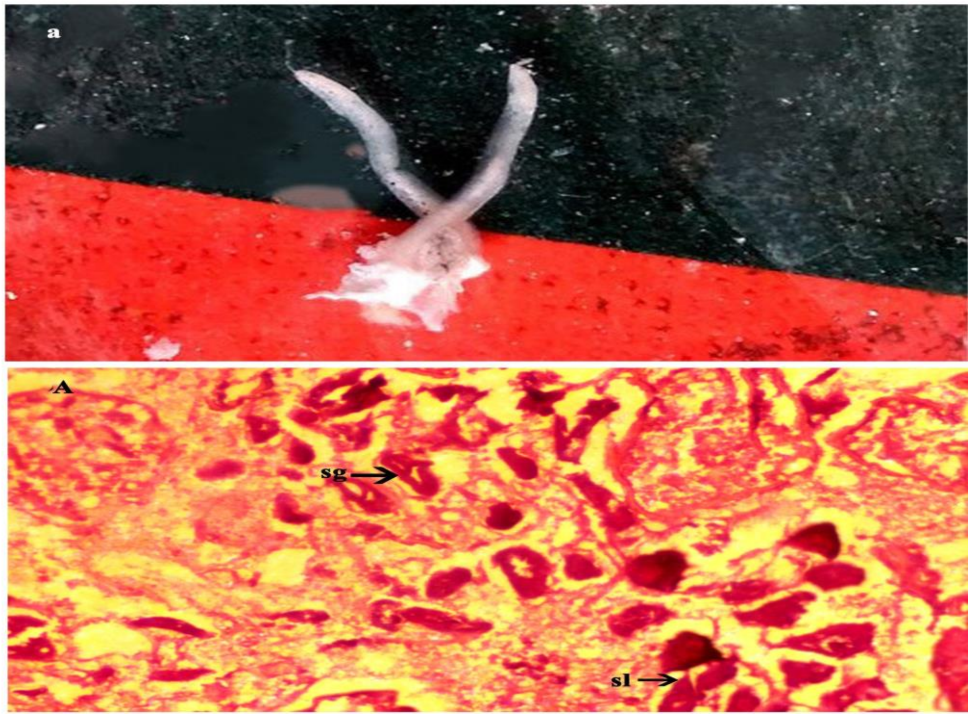

Fig. 3i. Gonad developmental stage of male of *S. muktijoddhai*; **a.** Immature gonad. **A.** Histological slide of immature stage (100x); Description: sg: spermatogonia; sl: seminiferous lobule

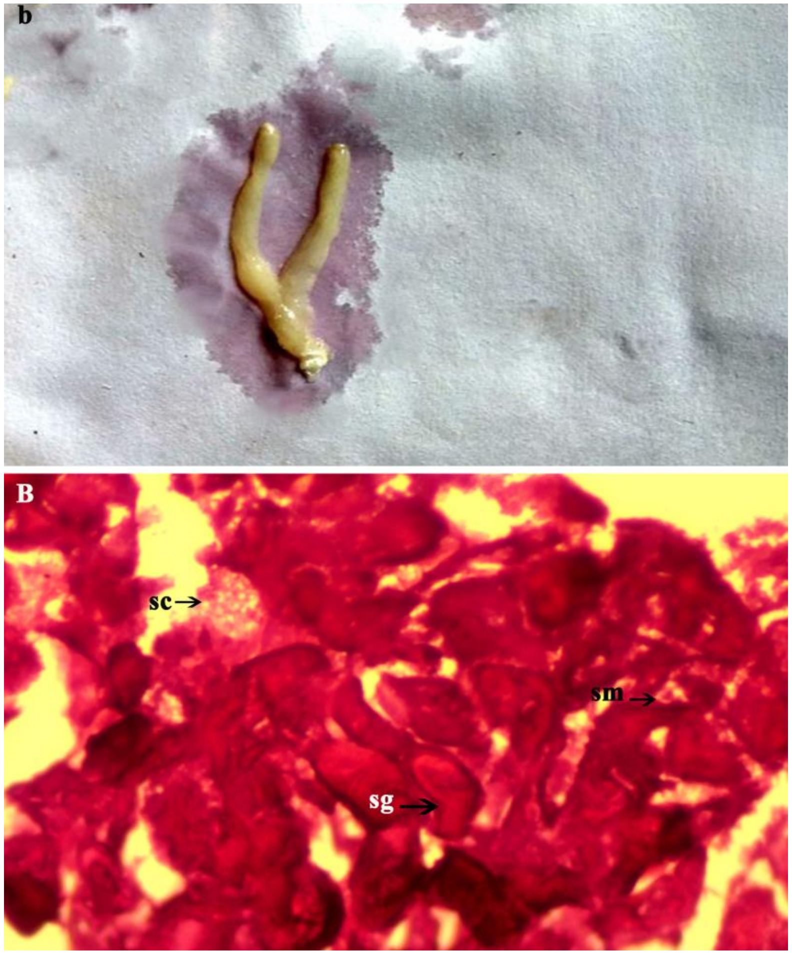

Fig. 3ii. Gonad developmental stage of male of *S. muktijoddhai*; **b.** Maturing gonad, **B.** Histological slide of maturing stage (100x); Description: sc: spermatocytes; sg: spermatogonia; sm: spermatids

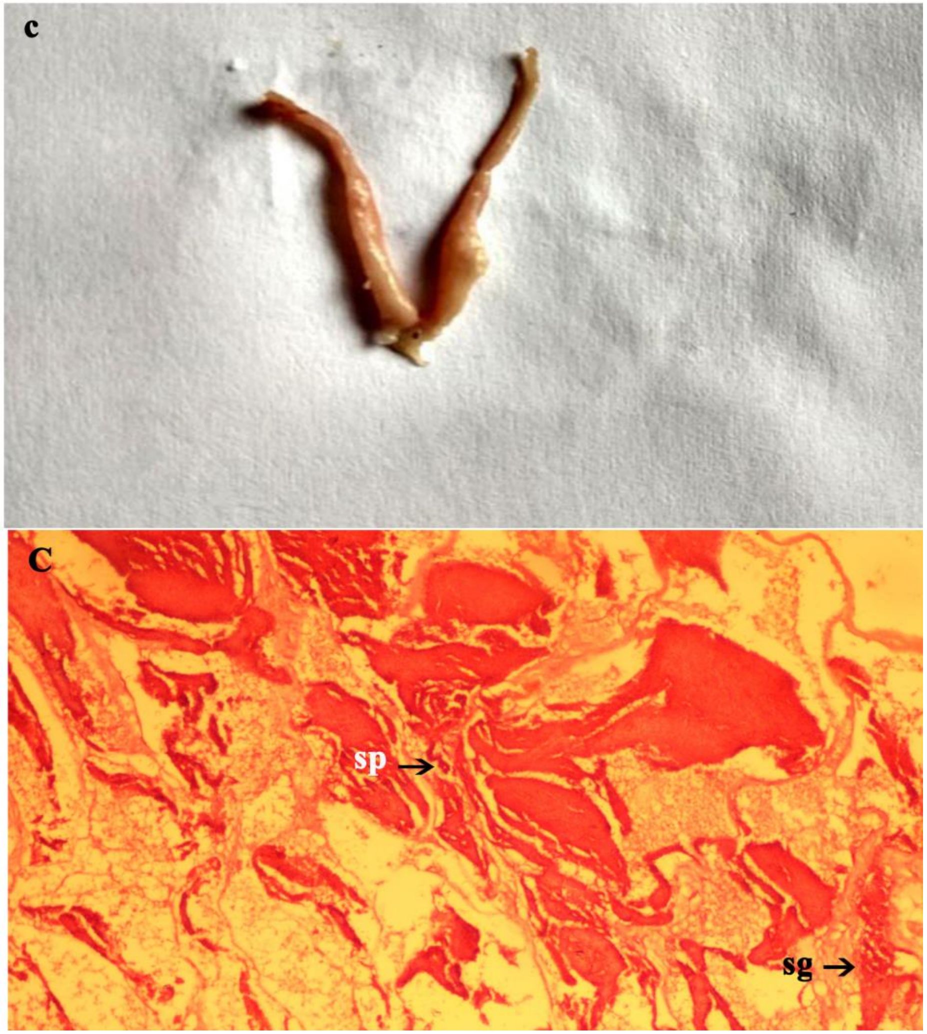

Fig. 3iii. Gonad developmental stage of male of *S. muktijoddhai*; **c.** Ripe gonad, **C.** Histological slide of ripe stage (100x); Description: sg: spermatogonia; sp: spermatozoa

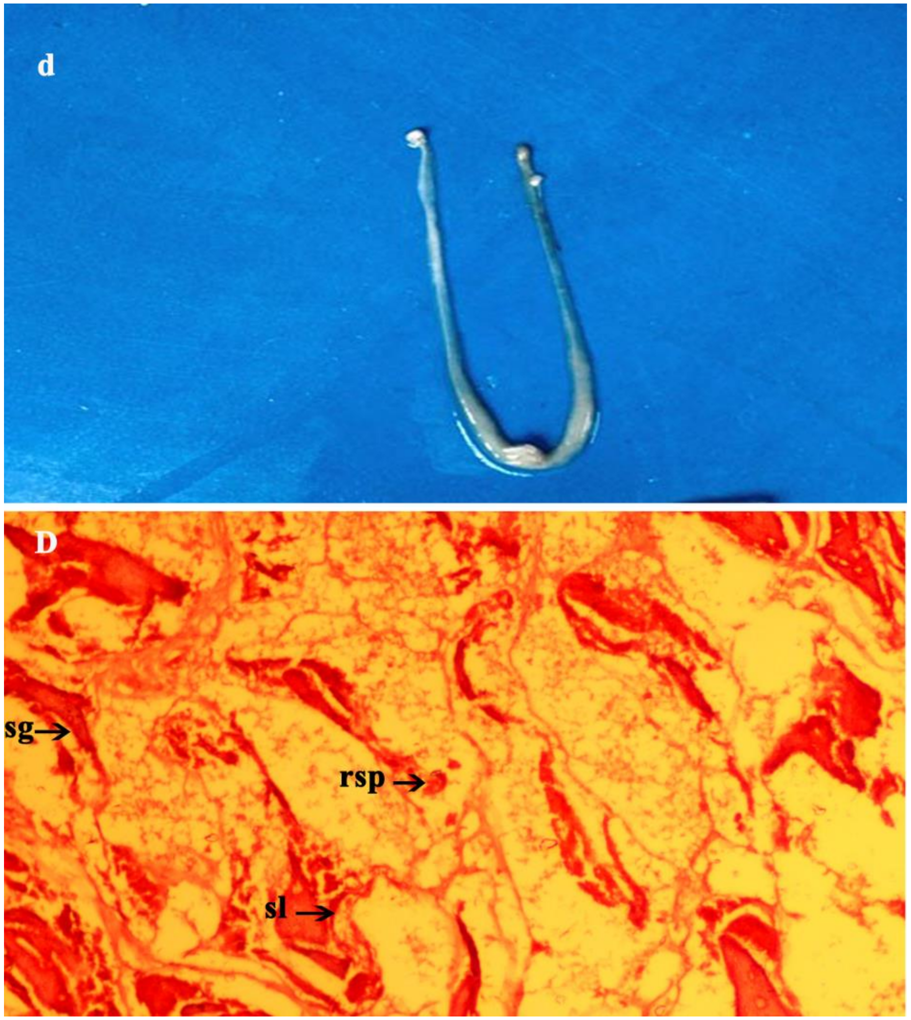

Fig. 3iv. Gonad developmental stage of male of *S. muktijoddhai*; **d.** Spent gonad, **D.** Histological slide of spent stage (100x); Description: sg: Spermatogonia; sl: Seminiferous lobule; rsp: Residual spermatozoa

Fig. 4. Gonad developmental stages of the female of *S. muktijoddhai*. **a.** Immature gonad, **b.** Maturing gonad, **c.** Mature gonad and d. Ripe gonad; **A.** Histological slide of immature stage (100x), **B.** Histological slide maturing stage (100x), **C.** Histological slide of mature stage (100x) and **D.** Histological slide of ripe stage (100x). Description: n: nucleus; ne: nucleolus; og: oogonia; po: primary growth oocytes; ca: cortica alveoli; yg: yolk globule; od: oil droplet; cm: cell membrane; hyg: hydrolyzed yolk granules

Table 2. Comparison between the characters of gonadal development of *S. muktijoddhai* and *S. sihama*

		Sillago muktijoddhai (present study)		*Sillago sihama* (Sawant et al., 2017, Mirzaei et al., 2013, Vinod and Basavaraja, 2010)	
Sex	Stages	Key features	Periods of occurrence	Key features	Periods of occurrence
Male	Immature	Testes threadlike, yellowish and comprised of sl, primary sg.	March and September	Testes thin, ribbonlike and characterized by the presence of sl, sc and sg.	September to February
	Maturing	Testes elongated and occupied most of the abdominal space and comprised of comparatively developed sg, sc, sl and sm.	September to October	Testes translucent, white colored and sp, sm, sg and sp are present.	September to February
	Ripe	Testes milky white and several sl, mature sp and sg are evident	October and November	Testes pale reddish color and comprised of confluence of several sl, mature sp.	March until July
	Spent	Testes sac-like, empty sl, residual sp and sg are observed	October and November	Testes consists of empty sl, some residual sp as well as sg is also evident	May to August
Female	Immature	Ovary thin, pinkish, and nearly occupied one-third of the abdominal cavity and og, po are present.	March	Ovary pinkish white and og, po and so are present	March and April
	Maturing	Ovary occupied most of the abdominal cavity and po, og, yg and ca are evident.	March and September	Gonads with visible nucleus and the presence of og, ca, po.	May
	Mature	Ovaries oblong and had a granular surface. Presence of og, po, ne, yg.	September and October	Ovaries transparent with opaque eggs and isolated layer of follicular epithelium, ripe oocyte, germinal vesicle and yolk vesicle are evident	July and August
	Ripe	Ovaries swollen and expended and characterized by hyg, ca and og.	October and November	Presence of large eggs, nucleus, yg, hyg and pof	October, November, December

Sc- Spermatocytes; Sg- Spermatogonia; Sm- Spermatids; Sl- Seminiferous lobule; Sp- Spermatozoa; Og- oogonia; Po- primary growth oocytes; Ca- Cortica Alveoli; Yg- Yolk globule; Ne- neucleolus; Cm- Cell membrane; Hyg- Hydrolyzed yolk granules; So- secondary oocytes; Pof- Post ovulatory follicle

3.5 Fecundity

The absolute fecundity was determined for 21 ripe fish with length and weight classes ranging from 157.77–161.55cm and 27.38–31.86 grams, respectively. The range of absolute fecundity varied from 6,164–30,555 eggs per ovary of fish with a mean value of 12,176 ± 1,050.19. The highest and lowest obtained relative fecundity was 959 and 117 eggs per gram of fish, with 185.56 and 161.55cm total length, respectively. However, the mean relative fecundity was 387 ± 46.376.

3.6 Relationship among fecundity and other parameters

A linear relationship was found for fecundity with different individual parameters, such as total length, body weight, gonad weight, and GSI of *S. muktijoddhai*. The correlation coefficient (r) referred to a positive significant relationship (*P*<0.05) between fecundity and gonad weight as well as fecundity and GSI (Fig. 5).

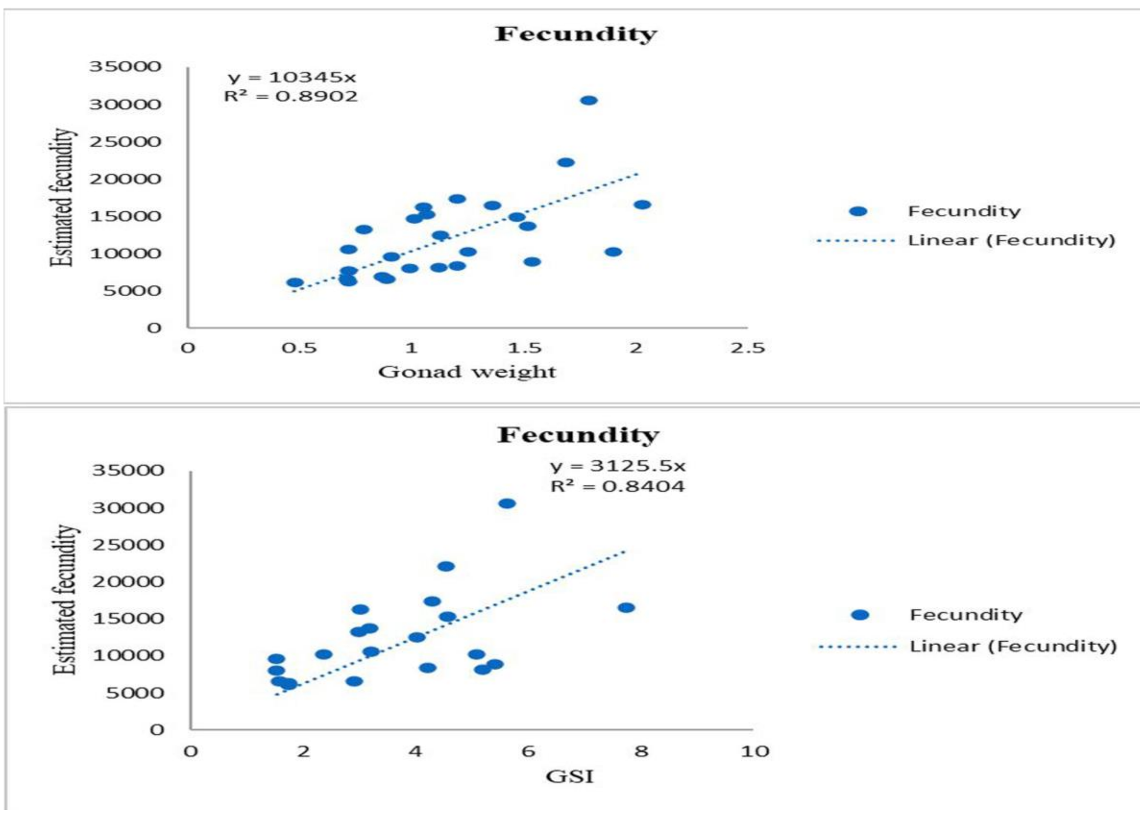

Fig. 5. Relationship of fecundity with gonad weight and GSI of *S. muktijoddhai*. **A.** Fecundity vs gonad weight; **B.** Fecundity vs GSI

4. Length-weight relationship

The data of LWRs suggested that the relationships were highly significant with a *P* -value less than 0.05, and $r^2 > 0.98$. However, a linear relationship between total length and body weight was evident in the present study. With respect to the calculated value of regression parameter, b for the total fish samples was 3.213, $r^2 = 0.973$, which indicated a positive allometric growth and was strongly significant. Furthermore, the value of 'b' for total males and females also showed the same growth pattern. In addition, for the monthly values of allometric coefficient, 'b' ranged from a minimum of 2.33 to a maximum of 3.06 for TL in females and those in males, the values ranged from 1.9 to 3.12 (Table 3).

5. Food and feeding habits

The present study considered the external characteristic, such as mouth morphometry and relative gut length as well as occurrence of gut contents in determining the food and feeding habits of the studied fish.

5.1 External features

An inferior mouth with moderate mouth gape and crescentic shape was observed in *S. muktijoddhai*. The jaw was unequal and hard, and the lip was thin. The villiform teeth were scattered all over the jaw, pharyngeal teeth were sharp and recurved inward. The body was compressed fusiform. The external features suggested that the fish might be a bottom feeder. Moreover, the morphometric study of their head also supported the bottom feeding tendency (Table 4). The structure of the teeth represented their carnivorous or omnivorous feeding habits. The mean relative gut length was found to be less than one for both males and females, which indicated their feeding habit as carnivore.

Table 3. Descriptive statistics of length-weight measurements of males and females of *S. muktijoddhai*

			Length	Weight	$W=aL^b$				
Month	Sex	N	TL (mm)	BW (gm)	A	95%of Cl for a	b	95% of Cl for b	r^2
August, 2022	Male	76	139.38–189.94	23.55–44.25	0.07	0.029–0.155	1.90	1.52–2.28	0.57
	Female	60	152.21–196.74	26.6–54.07	0.01	0.006–0.049	2.52	2.05–2.99	0.67
November, 2022	Male	60	51.23–168.25	3.37–37.41	0.01	0.003–0.005	3.12	3.03–3.22	0.99
	Female	40	76.1–172.88	2.74–40.63	0.01	0.004–0.006	3.06	2.96–3.16	0.99
March, 2023	Male	28	125.62–171.43	13.75–39.05	0.05	0.002–0.012	3.11	2.68–3.54	0.89
	Female	21	123.02–160.81	13.4–30.9	0.02	0.003–0.152	2.33	1.46–3.19	0.63
September, 2023	Male	57	157.17–193.92	28.65–42.87	0.01	0.001–-0.128	2.64	1.65–3.64	0.34
	Female	37	160.23–200.5	32.74–71.23	0.01	0.002–-0.016	3.01	2.56–3.46	0.84
October, 2023	Male	35	70.08–190.87	31.16–55.06	0.01	0.002–0.046	2.84	2.11–3.57	0.68
	Female	30	156.05–193.08	32.23–60.11	0.01	0.001–0.031	2.91	2.27–3.54	0.76
Total	Male	256	51.23–193.92	3.37–55.06	0.004	0.003–0.004	3.20	3.14–3.26	0.98
	Female	188	76.1–-200.5	2.74–71.23	0.003	0.003–0.004	3.23	3.17–3.34	0.96
	Combined	444	51.23–200.5	2.74–71.23	0.004	0.003–0.004	3.21	3.16–3.26	0.97

N- Sample size; a- Intercept of relationship; b- Slope of relationship; CI- Condition interval; r2- Coefficient of determination

Table 4. Morphometric measurements of the head and percentage of food contents on the gut of *S. muktijoddhai*

Morphometry of head			Monthly percentage of food contents					
Parameters	Range	Mean	Month	Crustacean	Molluscan	Zooplankton	Sand	Miscellaneous
Premaxillary distensibility	5.45–16.62	10.4	August, 2022	36.98	6.81	25.86	4.21	26.14
Lower jaw protrusability	3.32–15.42	8.45	November, 2022	45.74	8.29	28.73	3.83	13.41
Mouth aperture width (% of total length)	1.71–2.73	2.28	March, 2023	28.95	5.83	31.74	7.32	26.16
Mouth aperture height (% of total length)	3.36–5.33	4.06	September, 2023	55.51	3.68	21.97	3.98	14.84
			October, 2023	49.04	3.89	24.87	4.76	17.44

5.2 Gut contents

Analysis of gut contents showed that the crustaceans comprised their major food items with the highest percentage (43%) of occurrence (Fig. 6). Among the crustaceans, the shells, carapace, and appendages of crabs and prawns constitute the major parts. The highest percentage of crustacean intake was observed in September (55.51%) (Table 4). Sand represented the lowest percentage (5%) which indicates their bottom-feeding habit. The miscellaneous content comprised several materials, such as gills, flesh, fragments of stones, the least amount of phytoplanktonic material, mucus, and digested material which forms a major portion of the diet of *S. muktijoddhai*. The analysis of gut contents in the present study revealed that the majority of the diet of *S. muktijoddhai* was derived from animal sources. This also supported the fish as carnivores. The volume of the gut content in each sample in the present study represented that the fish reduced their feeding activity during March and August.

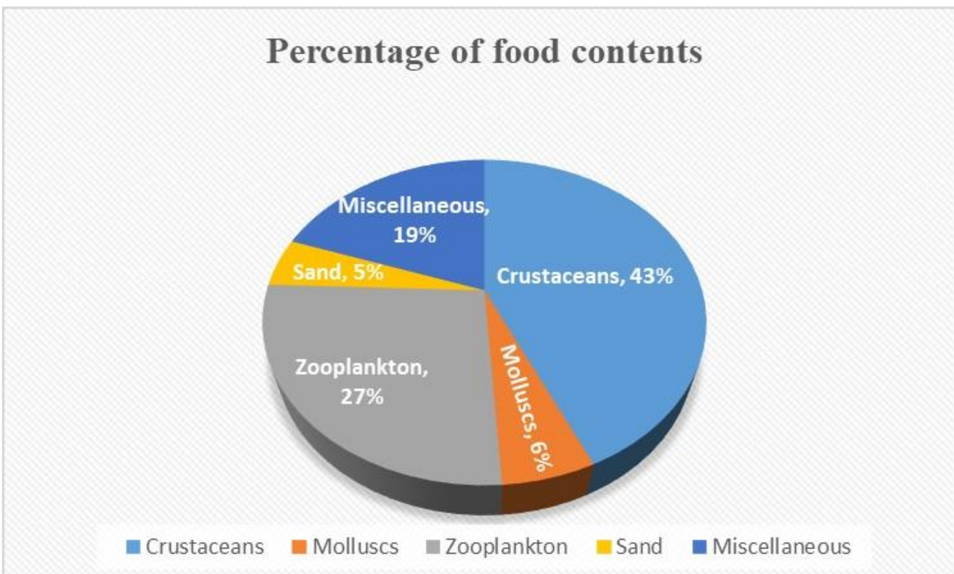

Fig. 6. Percentage of different types of food contents in the gut of *S. muktijoddhai*

DISCUSSION

Swim bladder structure along with the morphomeristic characters of the fish supported the diagnostic features of *S. muktijoddhai* previously described by **Saha *et al.* (2022, 2024)** and the species was identified morphologically. Additionally, the results of DNA barcoding showed a high similarity with reference sequences, further supporting the identification of the species as *S. muktijoddhai* based on molecular analysis.

The present study referred that the males of *S. muktijoddhai* dominated the natural population all over the sampling periods. This dominancy of males was also evident in the study of *Sillago vincenti*, *Sillago sihama*, *Sillago suezensis,* and *Sillaginopsis panijus* **(Khan *et al*., 2013; Manjappa *et al*., 2015; Erguden & Dogdu, 2020; Sabbir *et al*., 2022)**. However, the dominance of females over males were recorded in *S. sihama* and *S. suezensis* **(Mirzaei *et al*., 2013; Akel & Rizkalla, 2015)**. Whatever, variations in the sex ratio may be due to seasonal variations in populations, the age of sexual maturity, the length at maturity, and the difference in length distribution concerning depth **(Ismen *et al*., 2004)**.

A highest condition factor of the males of *S. muktijoddhai* than the females was recorded in all the sampling periods except for the month of March. However, *S. sihama* showed a higher value of the condition factor in July-November, July-February, February and May in several studies **(Krishnamurthy & Kaliyamurthy, 1978; Jayasankar, 1990; Shamsan & Ansari, 2010)**. In the case of *Sillago japonica*, the peak condition factor was observed in June and July **(Sulistiono *et al*., 2002)**. Moreover, the lowest condition factor for *Sillaginopsis panijus* was found during the months of January and August **(Krishnayya, 1963)**.

The peak spawning season for both the males and females of *S. muktijoddhai* was found in November. Similarly, November was also reported as the peak spawning season for closely related species of *S. muktijoddhai* such as *S. sihama* **(Checko, 1950; Radhakrishnan, 1957; Palekar & Bal, 1961; Jayasankar, 1990)**. In addition, the peak spawning season of *S. sihama* was observed in September-December for males and September-January for females **(Sawant *et al*., 2017)**. However, May was declared as the peak season for *S. sihama* **(Shamsan & Ansari, 2010)**. Moreover, the GSI value of *S. suezensis* was high in February-May with the highest in May **(Erguden & Dogdu, 2020)**. *Sillaginopsis panijus* showed the highest and lowest values in August and September, respectively **(Islam *et al*., 2012)**. These variations of GSI might be associated with changes in water temperature, salinity, and food supply, or perhaps with changes in the maturity stage **(Radhakrishnan, 1957)**.

The present study reported the ovary and testes of *S. muktijoddhai* had four developmental stages through histological observation. The observed characteristics of the ovary and testes of S. *muktijoddhai* were similar to that of *S. vincenti* **(Manjappa *et al*., 2015)**.

There was a considerable distinction in the estimated number of eggs in *S. muktijoddhai* with other related species. Moreover, there is also enormous variation in the estimated value of fecundity in *S. sihama* reported by different authors in different regions **(Palekar & Bal, 1961; Radhakrishnan, 1987; Jayasankar, 1991; Shamsan & Ansari, 2010)**. However, numerous factors such as fertility, the frequency of spawning, parental care, egg size, population density, geographical location, and most importantly environmental factors such as temperature, salinity, and availability of food are responsible for variations in fecundity in related species **(Bagenal, 1978; Rijnsdorp & Vingerhoed, 1994)**.

A positive allometric growth pattern was evaluated in case of *S. muktijoddhai* in the present observation. A similar observation was recorded in a closely related species, *S. sihama* **(Krishnomurthy & Kaliyamurthy, 1978; Jayasankar, 1991; Mirazaei *et al*., 2013; Muchlis *et al*., 2021)**. Moreover, for the regression coefficient, 'b' was the same for both the males and females of *S. sihama* from Mangalore waters **(Gowda *et al*., 1988)** which was also observed in the present study. In addition, a positive allometric growth was also recorded in *Sillaginopsis panijus* **(Pradhan *et al*., 2020)**. The current study also observed a variation in the values of regression parameter, "b" on different sampling periods for both the males and females. However, differences of 'b' values can be attributed to variation in sampling and preservation method, habitat, seasonal effects, sex, nutrition, condition of health **(Hasan *et al*., 2020; Sabbir *et al*., 2020)**, specimen handling, fishing gear type, environmental condition, or even decompensation during capture **(Hernández-Padilla *et al*., 2020)** which were not intentional in the present study. These influences may be standing single or in combination with others **(Hossen *et al*., 2020)**.

A bottom feeding tendency with similar external features of the fish was also evident **(Koundal *et al*., 2016)**. Fish are classified as carnivore when the relative gut length is less than one **(Athira & Revathy, 2021)** which is detected in the present study. The investigation of gut contents revealed the carnivorous habits of *S. muktijoddhai* where crustaceans were the major food items. Similar trends were also found in *S. sihama* **(Athira & Revathy, 2021)**. Moreover, digested and semi-digested materials were also evident in the gut contents of *S. sihama* (**Athira & Revathy, 2021**). The reduction of feeding activity during summer months was reported by some researchers in *S. sihama* **(Shamsan & Ansari, 2008; Taghavi *et al*., 2012)**. However, the feeding activity of *S. sihama* was reduced effectively during the summer months due to an increase in spawning activity **(Athira & Revathy, 2021)**. The changes in feeding activity may be due to the filling of the abdominal cavity by ripe gonads, resulting in nearly empty stomachs during summer **(Kariman *et al*., 2009)**.

CONCLUSION

The present study identified several key findings: The population was male-dominant; males exhibited a better growth condition than females; November was identified as the peak spawning period for both sexes; absolute fecundity ranged from 6,164 to 30,555 eggs per ovary; the length-weight relationship indicated a positive allometric growth pattern; and the fish is a bottom feeder and carnivorous in nature.

These findings provide essential biological data for further assessments of the population dynamics and stock status of *S. muktijoddhai*. Additionally, more extensive studies are needed to evaluate the distribution, ecological function, and fisheries management of this species in the future.

REFERENCES

Abdel-aziz, N.E. and Gharib, S.M. (2007). Food and feeding habits of round *Sardinella* (*Sardinella aurita*) in El-Mex Bay, Alexandria, Egypt. Egyptian Journal of Aquaculture Research, 33: 202-221.

Akel, E.S.H.K. and Rizkalla, S.I. (2015). A contribution to the fishery biology of an immigrant new species, *Sillago Suezensis* (Golani, Fricke & Tikochinski, 2014) (Family Sillaginidae), In the Egyptian Mediterranean Waters "Off Port Said". International Journal of Innovative Studies in Aquatic Biology and Fisheries, 1(1): 38-45.

Alam, M.M.; Galib, S.M.; Islam, M.M.; Flowra, F.A. and Hussain, M.A. (2012). Morphometric study of the wild population of pool barb, *Puntius sophore* (Hamilton, 1822) in the River Padma, Rajshahi, Bangladesh. Trends in Fisheries Research, 1(2): 10-13.

Alavi-yeganeh, M.S.; Mirhadi, S.N. and Nasri, M. (2016). Length-weight and length-length relationships for three *Sillago* species (Sillaginidae) from the Persian Gulf. Journal of Applied Ichthyology, 32(6): 1322-1323.

Annappaswamy, T.S.; Reddy, H.R.V. and Nagesh, T.S. (2004). Length-weight relationship of Indian sand whiting, *Sillago sihama* in Mulki estuary, Mangalore. Journal of Inland Fisheries Society India, 36: 18-22.

Athira, V. and Revathy, S. (2021). A study on food and feeding habits of *Sillago sihama* (Forsskal, 1775)- a candidate species for mariculture from Cochin waters. Journal of Zoology, 10: 17-24.

Bagenal, T.B. (1978). Aspects of fish fecundity. In: Ecology of freshwater fish production (ed. S. D. Gerking). Wiley, New York, 75-101.

Beverton, R.J.H. and Holt, S.J. (1957). On the dynamics of exploited fish populations. Fisheries Investigations, 19: 1-533.

Binohlan, C. and Pauly, D. (1998). The length-weight table, in: R. Froese, D. Pauly (Eds.). Fishbase: Concepts, design and data sources. ICLARM, Manila: 121-123.

Blaber, S.J.M. (1997). Fish and fisheries of tropical estuaries. London: Chapman and Hall, 367.

Blazer, V.S. (2002). Histopathological assessment of gonadal tissue in wild fishes. Fish Physiology and Biochemistry, 26: 85-101.

Chacko, P.I. (1950). Marine plankton from waters around the Krusadai Island. Proceedings of the Indian Academy of Sciences, 31: 162-174.

Chacko, P.I.; Mathew, M.J. and George, S. (1956). A preliminary study of the fisheries of the Korapuzha estuary, Malabar. Fisheries Statistics Reportand Year Book. April 1954 – March 1955 Madras: 109-112.

Coull, B.C.; Greenwood, J.G.; Fielder, D.R. and Coull, B.A. (1995). Subtropical Australian juvenile fish eat meiofauna: Experiments with winter whiting *Sillago maculata* and observations on other species. Marine Ecological Progress Series, 125(1-3): 13-19.

Demartini, E.E. and Sikkel, P.C. (2006). In: The Ecology of Marine Fishes: California and Adjacent Waters. LG Allen, DJ Pondella, and MH Horn (eds.). University of California Press, Berkeley:670.

Divya, P.R.; Kumar, R.G.; Joy, L.; Shanis, C.P.R.; Basheer, V.S. and Lal, K.K. (2021). Re-Description of *Sillago malabarica*, Silver Whiting from southern Indian waters. Thalassas: An International Journal of Marine Sciences, 37: 627-640.

Dutt, S. and Sujatha, K. (1980). On the seven species of fishes of the family Sillaginidae from Indian waters. Mahasagar, 13(4): 371-375.

Ergüden, D. and Doğdu, S.A. (2020). Age, growth and mortality estimates of *Sillago suezensis* from Iskenderun Bay, northeastern Mediterranean Sea. Cahiers de Biologie Marine, 61: 81-90.

Flores, A.; Wiff, R.; Ganias, K. and Marshall C.T. (2019). Accuracy of gonadosomatic index in maturity classification and estimation of maturity ogive. Fisheries Research, 210: 50-62.

Froese, R. (2006). Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology, 22(4): 241-253.

Ganias, K.; Somarakis, S. and Nunes, C. (2014). Reproductive potential. Biology and Ecology of Sardines and Anchovies: 79-121.

Gao, T.X.; Ji, D.P.; Xiao, Y.S.; Xue, T.Q.; Yanagimoto, T. and Setoguma, T. (2011). Description and DNA barcoding of a new sillago species, *Sillago sinica* (Perciformes: Sillaginidae), from coastal waters of China. Zoological Studies, 50: 254-263.

Golani, D.; Fricke, R. and Tikochinski, Y. (2013). *Sillago suezensis*, a new whiting from the northern Red Sea, and status of *Sillago erythraea* Cuvier (Teleostei: Sillaginidae). Journal of Natural History, 48(7-8): 413-428.

Gray, L.A. (1964). Dysplasia, carcinoma in situ and microinvasive carcinoma of the cervix uteri.

Greenwood, P.H.; Rosen, D.E.; Weitzmann, S.H. and Myers, G.S. (1966). Phyleticstudies of teleostean fishes, with a provisional classification of living forms. Bulletin American Museum of Natural History, 131: 339-455.

Gunn, J.S. and Milward, N.E. (1985). The Food, Feeding Habits and Feeding Structures of the Whiting Species, *Sillago sihama* (Forsskal) and *Sillago analis* Whitley from Townsville, North Queensland, Australia. Journal Fisheries Biology, 26(4): 411-427.

Hajisamae, S.; Yeesin, P. and Ibrahim, S. (2006). Feeding Ecology of Two Sillaginid Fishes and Trophic Interrelations with Other Co-existing Species in the Southern Part of South China Sea. Environmental Biology of Fishes, 76: 167-176.

Hajisamaea, S.; Choua, L.M. and Ibrahim, S. (2003). Feeding habits and trophic organization of the fish community in shallow waters of an impacted tropical habitat estuarine. Coast Shelf Sciences, 58: 89-98.

Hasan, M.R.; Mawa, Z.; Hassan, H.U.; Rahman, M.A.; Tanjin, S.; Abro, N.A.; Gabol, K.; Bashar, M.A.; Jasmine, S.; Ohtomi, J. and Hossain, M.Y. (2020). Impact of eco-hydrological factors on growth of the Asian stinging catfish *Heteropneustus fosslis* (Bloch, 1794) in a wetland ecosystem. Egyptian Journal of Aquatic Biology and Fisheries, 24: 77-94

Hernández-Padilla, J.C.; Capetillo-Piñar, N.; Aranceta-Garza, F.; Yee-Duarte, J.A.; Vélez-Arellano, N. and Velázquez-Abunader, I. (2020). Length-weight relationships of 12 marine fish species from the Pacific coast of Guatemala associated with small-scale fisheries. Journal of Applied Ichthyology, 36: 863-865.

Hossain, M.Y.; Hossen, M.A.; Ahmed, Z.F.; Hossain, A.M.; Pramanik, M.N.U.; Paul, A.K.; Nawer, F.; Khatun, D.; Haque, N. and Islam, M.A. (2017). Length–weight relationships of 12 indigenous fish species in the Gajner Beel floodplain (NW Bangladesh*)*. Journal of Applied Ichthyology, 33: 842-845.

Hossen, M.A.; Hossain, M.Y.; Khatun, D.; Pramanik, M.N.U.; Parvin, M.F.; Jasmin, J.; Sharmin, S.; Rahman, O.; Mawa, Z.; Rahman, M.A. and Hasan, M.R. (2020). Morphometric and meristic traits of three Ambassid fish species (*Chanda nama*, *Parambassis lala* and *Parambassis ranga*). Indian Journal of Geo-Marine Science, 49: 398-405

Hyndes, G.A. and Potter, I.C. (1996). Comparisons between the age structures, growth and reproductive biology of the two co-occurring sillaginids, *Sillago robusta* and *Sillago bassensis* in temperate coastal waters of Australia. Journal of Fish Biology, 49(1): 14-32.

Hyndes, G.A. and Potter, I.C. (1997). Age, growth and reproduction of *Sillago schomburgkii* in south-western Australia, nearshore waters and comparisons of life history styles of a suite of *Sillago* species. Environmental Biology of Fishes, 49: 435-447.

Hynes, H.B.N. (1950). The Food of Freshwater Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a Review of Methods Used in Studies of the Food of Fishes. Journal of Animal Ecology 19: 36-58.

Innal, D.; Kisin, B. and Akdoganbulut, D. (2015). Length-weight Relationships and Morphometry of *Sillago suezensis* from Antalya Gulf-Turkey. International Journal of Fisheries and Aquatic Studies, 2(4): 107-112.

Islam, M.R.; Sultana, N.; Hossain, B.M. and Mondal, S. (2012). Estimation of fecundity and gonadosomatic index (GSI) of Gangetic whiting, *Sillaginopsis panijus* (Hamilton, 1822) from the Meghna River estuary. World Applied Science Journal, 17(10): 1253-1260.

İşmen, A.; İşmen, P. and Başusta, N. (2004). Age, growth and reproduction of Tub Gurnard (*Chelidonichthys lucerne*, L. 1758) in the Bay of İskenderun in the Eastern Mediterranean. Turkish Journal of Veterinary & Animal Sciences, 28(2): 289-295.

Jayasankar, P. (1991). Length-weight relationship and relative condition factor in *Sillago sihama* (Forsskal) from Mandapam region. Indian Journal of Fisheries, 38(3): 183-186.

Jayasankar, P. and Alagarswamy, K. (1994). Histological and histochemical observations on the oocytes in the sandwhiting, *Sillago sihama* (Forsskal). Proceedings of the Indian National Science Academy, 60(2): 173-182.

Johnson, G.D. (1993). Percomorph phylogeny: progress and problems. Bulletin of Marine Sciences, 52(1): 3-28.

Kaga, T. and Ho, H.C. (2012). Redescription of *Sillago* (*Parasillago*) *indica* McKay, Dutt & Sujatha, 1985 (Perciformes: Sillaginidae), with a reassignment to the subgenus *Sillago*. Zootaxa, 3513: 61-67.

Kaga, T.; Imamura, H. and Nakaya, K. (2010). A new sand whiting, Sillago (*Sillago caudicula),* from Oman, the Indian Ocean (Perciformes: Sillaginidae). Ichthyology Research, 57: 367-372.

Kariman, A.S.H.; Shalloof and Nehad, K. (2009). Stomach Contents and Feeding Habits of *Oreochromis niloticus* (L.) From Abu-Zabal Lakes, Egypt. World Applied Sciences Journal, 6(1): 01-05.

Keast, A. and Webb, D. (1966). Mouth and Body Form Relative to Feeding Ecology in the Fish Fauna of a Small Lake, Lake Opinicon, Ontario. Journal of the Fisheries Board of Canada, 23: 12.

Keivany, Y.; Aalipour, M.; Siami, M. and Mortazavi, S.S. (2015). Length-weight relationships for three species from Beheshtabad River, Karun River basin, Iran. Iranian Journal of Ichthyology, 2(4): 296-298.

Khan, M.A. and Hoda, S.M.S. (1993). Sex ratio of the sole *Euryglossa orientalis* (Bl. & Schn.) (Family: Soleidae) from the Karachi coast. Pakistan Journal of Marine Sciences, 2: 157-159.

Khan, M.A.; Riaz, S. and Yousuf, K. (2015). Size distribution and length weight relationship in commercially important fish *Sillago sihama* (forsskal, 1775) (Family: Sillaginidae) from Karachi coast, Pakistan. International Journal of Biological Research, 3(2): 113-117.

Khan, M.A.; Yousuf, K. and Riaz, S. (2013). Observations on sex ratio and fecundity of *Sillago sihama* (Forsskal, 1775) (Family; Sillaginidae) from Karachi Coast. Journal of Entomology and Zoology Studies, 1: 152-157.

Khan, M.A.; Yousuf, K. and Riaz, S. (2014). Food and Feeding Habits of *Sillago sihama* (Forsskal,1775) (Family:Sillaginidae) from Karachi Coast. International Journal of Fauna and Biological Studies, 1(3): 27-31.

Khatun, D.; Hossain, M.Y.; Nawer, F.; Mostafa, A.A. and Al-askar, A.A. (2019). Reproduction of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. Environmental Science and Pollution Research, 26: 10800-10815.

King, M. (1995). Fisheries Biology: Assessment and Management. Fishing News Books Publ., Oxford, UK, ISBN-13: 978-0852382233, 341.

Koundal, S.; Koundal, A.; Sharma, I. and Dhanze, R. (2016). Mouth morphometry and body lengths with respect to the feeding habits of Hill stream fishes from Western Himalaya H.P. (India). International Journal of Fisheries and Aquatic Studies, 4(3): 346-356.

Krishnamurthy, K.N. and Kaliyanamurthy, M. (1978). Studies on the age and growth of sand whiting *Sillago sihama* (Forsskal) from Pulicat lake with observations on its biology and fishery. Indian Journal of Fisheries, 25(1 and 2): 84-97.

Krishnayya, C.G. (1963). On the use of otoliths in the determination of age and growth of the Gangetic whiting, *Sillaginopsis panijus* (Ham.Buch.), with notes on its fishery in Hooghly estuary. Indian Journal of Fisheries, 10: 391-412.

Kwak, S.N.; Baeck; Gun-wook and Sung-hoi (2004). Feeding Ecology of *Sillago japonica* in an Eelgrass (Zostera marina) Bed," Fisheries and aquatic sciences. Korean Society of Fisheries Science, 7(2): 84-89.

Larkin, M.A.; Blackshields, G.; Brown, N.P.; Chenna, R.; McGettigan, P.A.; McWilliam, H.; Valentin, F.; Wallace, I.M.; Wilm, A,; Lopez R et al. (2007). Clustal W and Clustal X version 2.0. Bioinformatics, 23: 2947-2948.

Lasker, R. (1985). An egg production method for estimating spawning biomass of pelagic fish. Technical Report NMFS 36, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, USA.

Lowerre-barbieri, S.; Ganias, K.; Saborido-rey, F.; Murua, H. and Hunter, J. (2011). Reproductive timing in marine fishes: variability, temporal scales, and methods. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 3(1): 71-91.

Manjappa, N.; Basavaraja, N. and Anjaneyappa, H.N. (2015). Reproductive biology of estuarine whiting, *Sillago vincenti* (McKay, 1980). Journal of Aquaculture in the Tropics; New Delhi, 30: 95-110.

McKay, R.J. (1985). A revision of the fishes of the family Sillaginidae. Memoirs of the Queensland Museum, 22: 73.

McKay, R.J. (1992) FAO species catalogue. Sillaginid fishes of the world (Family Sillaginidae): an annotated and illustrated catalog of the *sillago*, smelt or Indo-Pacific whiting species known to date. FAO, 14: 1-87.

Mirzaei, M.R.; Valinasab, T.; Yasin, S. and Hwai, A.T.S. (2013). Reproduction characteristics and length- weight relationships of the sand whiting (*Sillago sihama)* in the south coastal of Iran (Persian Gulf and Oman Sea). Annals of Biological Research, 4: 269-278.

Mohammed, A.R.M.; Mutlak, F.M. and Saleh, J.H. (2003). Food Habits of *Sillago sihama* (Forskal) in the Iraqi Marine Waters, Northwest Arabian Gulf, Iraq. Marina Mesopotamica, 18(1): 35-42.

Muchlis, N.; Prihatiningsih and Restiangsih, Y.H. (2021). Biological characteristics of silver sillago (*Sillago sihama*, Forsskal) in Bombana Water, South East Sulawesi. Earth and Environmental Science,674; 012010. IOP publishing.

Muchlisin, Z.A. (2013). Study on potency of freshwater fishes in Aceh waters as a basis for aquaculture and conservation development programs. Jurnal Iktiologi Indonesia, 13(1): 91-96.

Natarajan, A.V. and Jhingran, A.G. (1961). Index of Preponderance- A Method of Grading the Food Elements in the Stomach Analysis of Fishes. Indian Journal of Fisheries, 8: 54-59.

Nelson, J.S.; Grande, T.C. and Wilson, M.V.H. (2016). Fishes of the world (5th Eds.). John Wiley, Sons.

Offem, O.B.; Samsons, Y.A. and Omoniyi, I.T. (2008). Diet, size and reproductive biology of the silver catfish, *Chrysichthys nigrodigitatus* (Siluformes: Bagridae) in the Cross River, Nigeria. Revista de Biología Tropical: 56.

Palekar, V.C. and Bal., D.V. (1961). Studies on the food and feeding habits of the Indian whiting (*Sillago sihama*, Forsskål) from Karwar waters. Journal of the University, Bombay (Ns), 27: 1-18.

Palekar, V.C. and Bal., D.V. (1961). Studies on the maturation and spawning of the Indian sand whiting *Sillago sihama* from Karwar waters. Department of Zoology, Institute of Science, Bombay, 54: 76-93.

Panhwar, S.K.; Farooq, N.; Qamar, N.; Shaikh, W. and Mairaj, M. (2017a). A new *Sillago* species (family Sillaginidae) with descriptions of six Sillaginids from the Northern Arabian Sea. Marine Biodiversity, 48: 1-7.

Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Tech. Pap., FAO Rome, 234, 52.

Pradhan, R.S.; Roul, S.K.; Ghosh, S.; Tripathy, P.; Jaiswar, A.K.; Bhusan, S. and Nayak, B.B. (2020). Biometry, length-weight and length-length relationships of flathead Sillago, *Sillaginopsis panijus* (Hamilton, 1822) (Perciformes: Sillaginidae) from the north-western Bay of Bengal. Indian Journal of Fisheries, 67(3): 144-151.

Pramanik, D.S. and Mohanty, S.S. (2016). Length-weight relationship and biology of some common edible fish species at Chandipur, Bay of Bengal, Odisha. International Journal of Fisheries and Aquatic Studies, 4(1): 335-340.

Radhakrishnan, N.A. (1957). Contribution to the biology of Indian Sand Whiting, *Sillago sihama* (Forsskal 1775). Indian Journal of Fisheries, 4(2): 254-283.

Rahman, M.H. and Tachihara, T. (2005). Reproductive biology of *Sillago aeolus* in Okinawa Island, Japan. Fisheries Sciences, 71(1): 122-132.

Rao, L.M. and Sivani, G. (1996). The food preferences of five commercially important fishes of Gosthani estuary. Indian Journal of Fisheries, 43(2): 199-202.

Reddy, C.R. and Neelakantan, B. (1993). Relative condition factor and gonado-somatic index in *Sillago sihama* (Forrskal). Indian Journal of Fisheries, 40: 171-174.

Richardson, J. (1846). Report on the Ichthyology of the seas of China and Japan. Report of the British Association for the Advancement of Science, 15th meet, 1885, 187-320.

Rijnsdorp, A. and Vingerhoed, B. (1994). The ecological significance of geographical and seasonal differences in egg size in sole *Solea solea* (L.). Netherlands Journal of Sea Research, 32: 255-270.

Rounsefell, G.A. and Everhart, W.H. (1953). Age and growth. In: Fisheries Sciences, John Willey and Sons, New York:297-327.

Sabbir, W.; Hossain, M.Y. and Khan, M.N. (2022). Biometric Indices of Flathead Sillago, *Sillaginopsis panijus* (Hamilton, 1822) from the Bay of Bengal (Southern Bangladesh). Thalassas, 38: 811-820.

Sabbir, W.; Hossain, M.Y.; Mawa, Z.; Hasan, M.R.; Rahman, M.A.; Islam, M.A.; Tanjin, S.; Rahman, M.A.; Sarker, B.K. and Khan, M.N. (2020). New maximum size record, length-weight relationships and form factor of Hooghly croaker Panna *heterolepis Trewavas*, 1977 from the Bay of Bengal (Bangladesh). Lakes and Reservoirs: Research and Management, 25(3): 346-349.

Saha, S.; Bogorodsky, S.V.; Baki, M.A.; McKay, R.J.; Qin, J. and Gao, T. (2024). Assessment of the diversity of the family Sillaginidae in the Indian Ocean, with emphasis on the taxonomic identity of *Sillago sihama*. Zootaxa, (accepted).

Saha, S.; Song, N.; Yu, Z.; Baki, M.A.; McKay, R.J.; Qin, J. and Gao, T. (2022). Description of two new species, *Sillago muktijoddhai* sp. nov. and *Sillago mengjialensis* sp. nov. (Perciformes: Sillaginidae) from the Bay of Bengal, Bangladesh. Fishes, 7: 93.

Salam, A. and Mahmood, J.A. (1993). Weight-length and condition factor relationship of a freshwater under yearling wild *Catla catla* (Hamilton) from river Chanab (Multan). Pakistan Journal of Zoology, 25: 127-130.

Sambrook, J.; Fritsch, E.F. and Maniatis, T. (1989). Molecular cloning: a laboratory manual (2nd ed.). New York: Cold Spring Harbor Laboratory Press.

Sarkar, U.K.; Negi, R.S.; Deepak, P.K.; Lakra, W.S. and Paul, S.K. (2008). Biological parameters of the endangered fish *Chitala chitala* (Osteoglossiforms: Notopteridae) from some Indian rivers. Fisheries Research, 90: 170-177.

Sawant, P.; Nirmale, V.; Metar, S.; Bhosale, B. and Chogale, N. (2017). Biology of Indian sand whiting, *Sillago sihama* (Forsskal) along the Ratnagiri coast. Indian Journal of Geo Marine Sciences, 46(09): 1899-1907.

Schooner, T.W. (1974). Resource partitioning in ecological communities. Science, (Washington, D.C.) 185: 27-39.

Seher, D. and Suleyman, C.I. (2012). Condition factors of seven cyprinid fish species from Çamligöze Dam Lake on central Anatolia, Turkey. African Journal of Agricultural Research, 7(31): 4460-4464.

Shamsan, E.F. and Ansari, Z.A. (2008). Ecobiology and fisheries of an economically important estuarine fish, *Sillago sihama* (Forsskal). Thesis submitted for the degree of doctor of philosophy In Marine Science, Goa University.

Shamsan, E.F. and Ansari, Z.A. (2009). Studies on the reproductive biology of Indian sand whiting. *Sillago sihama* (Forsskal). Indian Journal of Marine Sciences, 39: 280-284.

Shamsan, E.F. and Ansari, Z.A. (2010). Studies on the reproductive biology of Indian sand whiting, *Sillago sihama* (Forsskal). Indian Journal of Marine Sciences, 39: 68-73.

Shamsan, E.F. and Ansari, Z.A. (2010). Study of age and growth of Indian sand whiting, *Sillago sihama*, (Forskål) from Zuari estuary, Goa. Indian Journal of Geo-Marine Sciences, 39(1): 68-73.

Simon, K.D. and Mazlan, A.G. (2008). Length-Weight and Length-Length Relationships of Archer and Puffer Fish Species. The Open Fish Science Journal, 1: 19-22.

Simon, K.D.; Mazlan, A.G.; Cob, Z.C.; Samat, A. and Arshad, A. (2008). Age determination of archer fishes (*Toxotes jaculatrix* and *Toxotes chatareus*) inhabiting Malaysian estuaries. Journal of Biological Sciences, 8(6): 1096-1099.

Sulistiono, M.Y.; Kitada, S. and Watanabe, S. (1999). Age and growth of Japanese whiting, *Sillago japonica* in Tateyama Bay. Fisheries Science, 65: 117-122.

Sulistiono, M.Y.; Wibisana, I.; Sari, P.P.; Affandie, R.; Watanabe, S. and Yokota, M. (2002). Maturity and food habits of the Japanese whiting (*Sillago japonica*) in Omura Bay, Nagasaki, Japan. Jurnalllmu-ilmu Perairan dan Perikanan Indonesia, 9(2): 121-128.

Taghavi-Motlagh, A.; Hakimelahi, M.; Ghodrati, S.M.; Vahabnezhad, A. and Taheri, M.A. (2012). Feeding habits and stomach contents of silver sillago, *Sillago sihama*, in the northern Persian Gulf. Iranian Journal of Fisheries Sciences, 11(4): 892-901.

Tsikliras, A.C. and Koutrakis, E.T. (2013). Growth and reproduction of European sardine, *Sardina pilchardus* (Pisces: Clupeidae), in the northeastern Mediterranean. Cahiers de Biologie Marine, 54: 365-374.

Vazzoler, A. (1996). Reproduction biology of teleostean fishes: theory and practice. Moringa, EDUEM. Brazilian Society of Ichthyology: 161.pages？

Vinod, B.H. and Basavaraja, N. (2010). Reproductive biology of the Indian sand whiting, *Sillago sihama* (Forssakal)- maturity stages, fecundity, spermatozoa and histology of gonads. Journal of Fish Biology, 30: 589-595.

Ward, R.D.; Zemlak, T.S.; Innes, B.H.; Last, P.R. and Hebert, P.D. (2005). DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1462): 1847-1857.

Xiao, J.G.; Song, N.; Han, Z.Q. and Gao, T.X. (2016A). Description and DNA barcoding of a new *Sillago* species, *Sillago shaoi* (Perciformes: Sillaginidae), in the Taiwan Strait. Zoological Studies, 55: 1-18.

Xiao, J.G.; Yu, Z.S.; Song, N. and Gao, T.X. (2021). Description of a new species, *Sillago nigrofasciata* sp. nov. (Perciformes, Sillaginidae) from the southern coast of China. ZooKeys, 10**(**11): 85-100.

Yu, Z.S.; Guo, T.; Xiao, J.G.; Song, N. and Gao, T.X. (2022). Identification and DNA barcoding of a new *Sillago* species in Beihai and Zhanjiang, China, with a key to related species. Journal of Ocean University of China, 21:1334-1342.

Yusoff, M.Y. (2013). Gonad development and diets of silver sillago (*Sillago sihama*) in the Marudu Bay, Sabah. Thesis, Universiti Putra Malaysia Serdang, Selangor.