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Biometry, length-weight and length-length relationships of flathead sillago *Sillaginopsis panijus* (Hamilton, 1822) (Perciformes: Sillaginidae) from the north-western Bay of Bengal

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ABSTRACT

Biometry, length-weight relationships (LWRs) and length-length relationships (LLRs) of *Sillaginopsis panijus* (Hamilton, 1822) were investigated in the Indian coast of north-western Bay of Bengal. Altogether 622 specimens were collected between August 2018 and September 2019 from landings by trawls (30-35 mm mesh size), gillnets (15-55 mm mesh size) and shore seines (7-15 mm bag mesh size). The total length and weight of the specimens ranged from 7.8-40.3 cm and 2.9-506 g, respectively. The LWR established was $W=0.0048 L^{3.059}$ for males, $W=0.0032 L^{3.185}$ for females and $W=0.0047 L^{3.0645}$ for indeterminates, indicating positive allometric growth pattern. All the LWRs were highly significant ($p<0.001$, $r^2\geq 0.977$). The highest coefficient of correlation (r) was observed for total length against fork length (0.999) and lowest for head length against eye diameter (0.951). The fin formula was expressed as $D_1 X, D_2 I + 24-28, P 17-22, V I + 5, A II + 25-27, GR 2-3/6-9$. The study provides the first detailed account of the biometric relationships of *S. panijus* in the north-western Bay of Bengal, which can be used as baseline information for subsequent biological and population based studies in the region.

Keywords: Biometry, Flat head sillago, Length-weight relationship, North-western Bay of Bengal, *Sillaginopsis panijus*.

Length-weight relationships (LWRs) have a necessary role in stock/ecological assessment, monitoring and management (Sinovicic *et al.*, 2004; Froese, 2006). As there are limitations in fisheries data collection, the use of LWRs is less time consuming and helpful to derive weight from length and *vice-versa* (Pauly, 1993). Estimation of mean weight from the length class is essential to assess the biomass through analytical models such as cohort or virtual population analysis (Andrade and Campos, 2002; Morey *et al.*, 2003). LWRs can also be used in estimating the number of fish landed and for comparing the population over space and time (Beverton and Holt, 1957; Thomas *et al.*, 2003). It is used to differentiate populations of the same species in different environments (Goncalves *et al.*, 1997). The prime aim of collecting information on length and weight of fishes in tropical conditions is to know the biomass, health condition and to fit the data in stock assessment models. LWRs are used as an index of survival, growth, maturity, reproduction and general wellbeing (Le Cren, 1951). Any deviation from the established relationship indicates changes in the

ecology of the habitat or the physiology of the fishes or both (Ghosh *et al.*, 2010).

Morphometric and meristic parameters are most frequently used to delineate stocks of commercially exploited fish species (Murta, 2000; Silva, 2003; O'Reilly and Horn, 2004; Turan, 2004). Species originating from different geographical areas often differ in their morphological parameters (Francicevic *et al.*, 2005). Morphological variations represent stock characteristics and the difference in body shape reveals different growth, mortality or reproductive rates of the stock (Swain and Foote, 1999; Cadrin, 2000; Hossain *et al.*, 2006). These characters are the most common and effective tools used to characterise the stock, determining fish assemblages and to distinguish between populations (Cheng *et al.*, 2005; Siddik *et al.*, 2016a, b) and thus, are essential for the conservation and management of exploited fisheries resources (Hossain *et al.*, 2012).

The family Sillaginidae comprises 14 species along the Indian coast (Froese and Pauly, 2019) and 6 species along north-western Bay of Bengal (Barman *et al.*, 2007).

The flathead sillago *Sillaginopsis panijus* (Hamilton, 1822) is a demersal inshore marine and estuarine fish distributed in Bangladesh, India, Myanmar, Malaysia and the Indonesian Archipelago (McKay, 1992). It is in very good demand in both, local and distant markets and is considered a delicacy due to its white meat and less intramuscular bones (Islam *et al.*, 2012). Studies on biology of the flathead sillago are limited and very little scientific literature is available worldwide (Islam *et al.*, 2012; Hossain *et al.*, 2015; Siddik *et al.*, 2015, 2016a). Hence, the present study aimed to investigate the biometry, length-weight relationship (LWRs) and length-length relationship (LLRs) of *S. panijus* collected along the north-western Bay of Bengal.

Specimens of *S. panijus* were collected fortnightly from Kirtonia Landing Centre (21°34'20.0784"N; 87°22'32.4336"E), Bahabalpur Landing Centre (21°30'46.6812"N; 87°6'54.2484"E), Balaramgadi Landing Centre (21°28'22.5048"N; 87°3'18.9792"E), Dhamra Fishing Harbour (20°47' 34.89"N; 86°54'01.38"E) and Paradeep Fishing Harbour (20°17'22.97"N; 86°42'25.51"E) along the north-east coast of India, between August 2018 to September 2019 (Fig. 1) from landings by trawls (30-35 mm mesh size), gillnets (15-55 mm mesh size) and shore seines (7-15 mm bag mesh size). Fresh specimens without any physical

damage were brought to the laboratory in iced condition for further studies. All the morphometric characters were measured using a digital vernier calliper with 0.1 cm accuracy and body weight by an electronic weighing balance with 0.1 g accuracy. Morpho-meristic characters were recorded following the standard method given by Hubbs and Lagler (1958). Specimens were sexed and categorised as male, female and indeterminate based on the macroscopic observation of gonads. Individuals were designated as indeterminates when the gonads were not identified macroscopically.

Altogether, 622 specimens of *S. panijus* comprising of 56 males, 460 females and 106 indeterminates were analysed for LWRs. The length-weight relationships for male, female and indeterminate were calculated separately using the equation given by Le Cren (1951): $W = a L^b$, where W is the body weight (g), L is the total length (cm), ' a ' is the intercept related to body form and ' b ' is the growth coefficient. The parameters ' a ' and ' b ' were estimated by a simple linear regression after logarithmic transformation of length and weight data, $\text{Log}(W) = \text{Log}(a) + b \text{Log}(L)$ (Froese, 2006). Extreme outliers were removed from the regression analysis by performing a log-log plot of the length-weight pairs (Froese, 2006). The statistical significance level of coefficient of determination

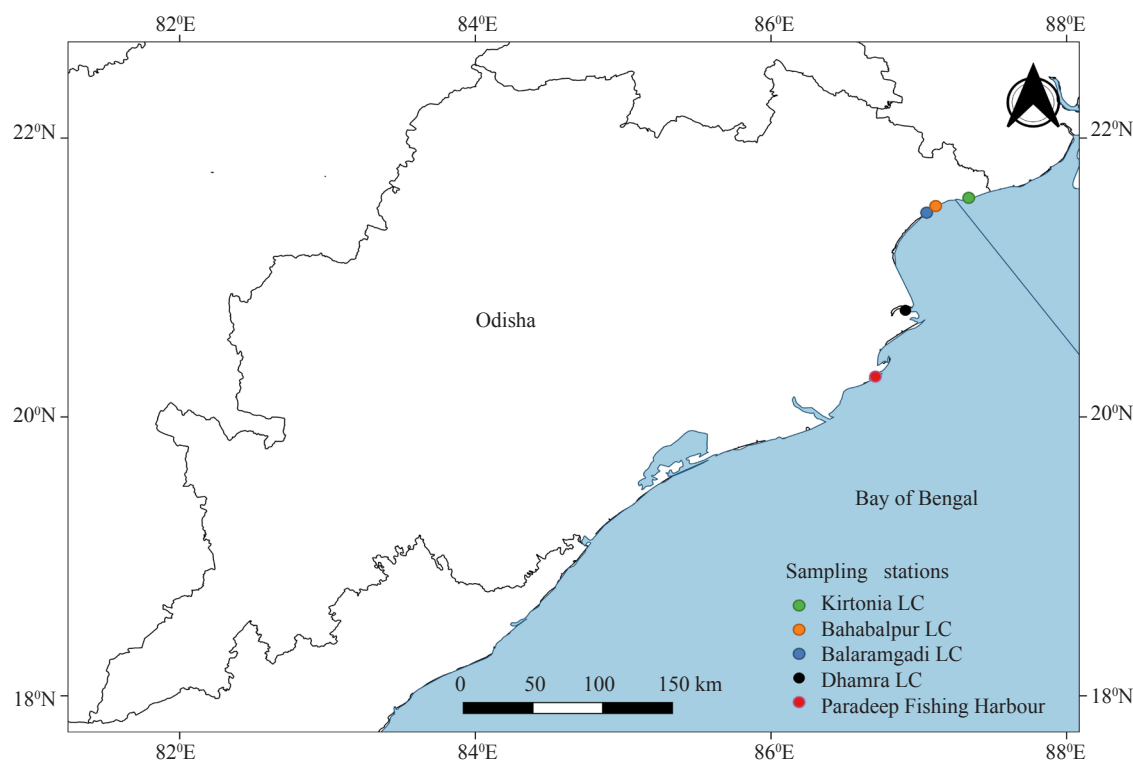


Fig. 1. Map showing the sampling stations of *S. panijus* along the north-western Bay of Bengal.

(r^2) and the 95% confidence limits (CI) of parameters 'a' and 'b' were calculated.

A total of 22 morphometric and 8 meristic characters were recorded for 57 individuals of various size ranges. The morphometric characters viz., total length (TL), standard length (SL), fork length (FL), head length (HL), head depth (HD), eye diameter (ED), pre-orbital length (PrOL), post-orbital length (PsOL), pectoral fin length (PtL), pelvic fin length (PeL), pre-first dorsal length (PDL1), pre-second dorsal length (PDL2), pre-pectoral length (PPeL), pre-pelvic length (PPeL), pre-anal length (PAL), inter-orbital width (IOW), body depth (BD), body width (BW), caudal depth (CD), lower jaw length (LJL) and upper jaw length (UJL) as well as meristic counts viz., dorsal fin rays, pectoral fin rays, pelvic fin rays, anal fin rays, gill rakers (upper and lower gill raker of left side gill arch) and scales above, below and on the lateral line were recorded. The relationships between the different morphometric characters (body measurements against the total length and head parts measurements against the head length) were established using linear regression analysis with $Y = a + b \times X$, where Y is dependent variable, X is independent variable, a is constant (intercept) and b is regression coefficient (slope). All the morphometric measurements are depicted in Fig. 2.

All analyses were performed using SPSS 19.0 software package (SPSS Inc., Chicago, USA) and MS Excel (Microsoft Office 2016). Analysis of covariance (ANCOVA) was done to determine the variation in 'a' (intercept) and 'b' (slope) values among the sexes at 5% level of significance. Student's t-test was applied to confirm the significant difference of 'b' value between the sexes.

A total of 622 specimens were collected for the study of which male constituted 9% ($n = 56$), female 74% ($n = 460$) and indeterminate 17% ($n=106$). The length range for

males was 11-33.2 cm TL and for females was 9.9-40.3 cm TL with mean \pm SE at 23 \pm 4.5 cm TL and 26 \pm 5.4 cm TL, respectively. From Bangladesh waters, the total length of *S. panijus* ranged from 14.6-29.3 cm (Siddik *et al.*, 2015) and 17.4-34.0 cm (Hossain *et al.*, 2015). The maximum length reported by Islam *et al.* (2012) from Meghna Estuary in Bangladesh was 38.2 cm. In the present study, the maximum total length was observed as 40.3 cm, which is closer to its maximum reported length of 44.0 cm (Talwar and Jhingran, 1991).

The overall sex ratio (male: female) was estimated at 1:8.2, which differs from Siddik *et al.* (2015) and clearly indicated that the population is dominated by females, with a deviation from the expected ratio of 1:1.

Scatter plot of length-weight relationship has been depicted separately for males, females and indeterminates of *S. panijus* (Fig. 3). The b value for male, female and indeterminate was found to be 3.059, 3.185 and 3.0645 respectively, showing positive allometric growth pattern in the species. Length-weight relationship was established as:

$$\text{Male: } W = 0.0048 L^{3.059} (r^2 = 0.983)$$

$$\text{Female: } W = 0.0032 L^{3.185} (r^2 = 0.977)$$

$$\text{Indeterminate: } W = 0.0047 L^{3.0645} (r^2 = 0.985)$$

The analysis of covariance (ANCOVA) revealed a significant difference in intercepts (a) and slopes (b) of the regression lines ($F = 1582.68$, $df = 514$, $p < 0.05$) between the sexes. Hence, the LWRs were established separately for both the sexes. The Student's t-test showed that difference between the mean length of male (22.9 cm) and female (26.4 cm) was found to be significant ($p < 0.05$) ($t = -4.531$, $df = 514$, $d = -3.427$). The descriptive statistics and estimated parameters of the LWRs of *S. panijus* are

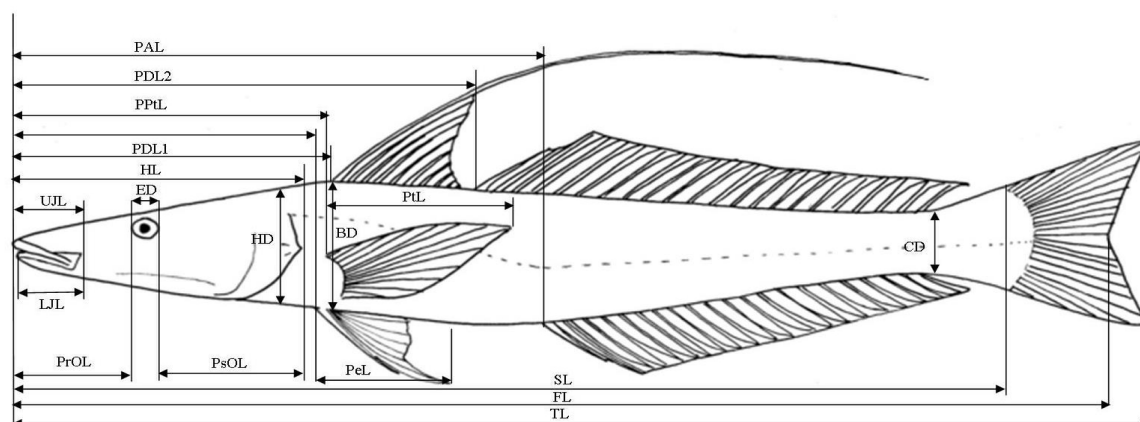


Fig. 2. Morphometric measurements of *S. panijus*.

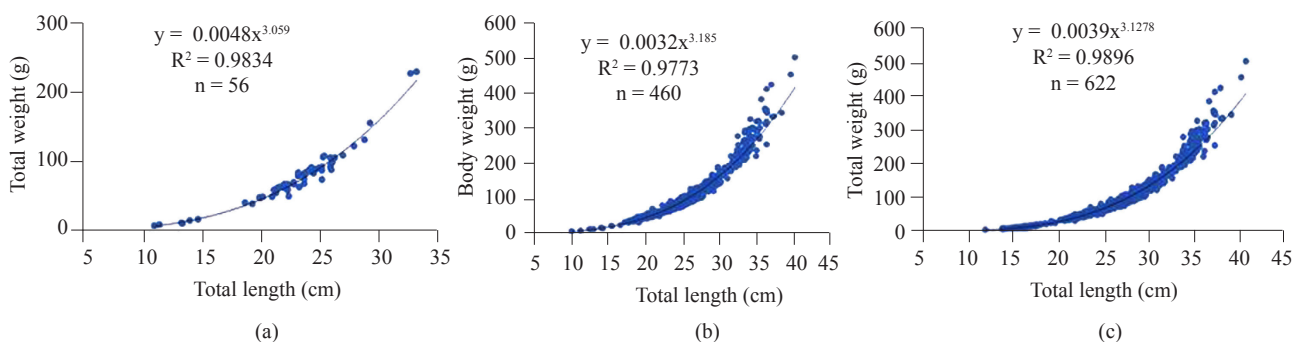


Fig. 3. Length-weight relationship of *S. panijus*. (a) Male, (b) Female, (C). Indeterminate

shown in Table 1.

The study confirmed positive allometric growth in *S. panijus* for male ($b = 3.059$) and female (3.185), which are in agreement with the findings of Siddik *et al.* (2015), where positive allometric growth for female ($b = 3.209$) and pooled sex ($b = 3.096$) and negatively allometric growth for male ($b = 2.994$) were reported in the Gangetic Delta, Bangladesh (Siddik *et al.*, 2015). Similar finding was also observed by Islam *et al.* (2012) in the Meghna River Estuary, Bangladesh and Hossain *et al.* (2015) in the Tetulia River, southern Bangladesh, wherein the b value was reported as 3.48 and 3.30, respectively. However, our study revealed a lower b value as compared with all the previous investigations. This difference in b values is attributed to the variations in the sampled size ranges caused due to exploitation by a variety of gears.

The descriptive statistics for all the morphometric characters are presented in Table 2. Analysis of the morphometric data showed the highest coefficient of

variation for lower jaw length (48%), followed by body width (46.2%) and upper jaw length (44.7%), whereas lowest was recorded for eye diameter (30%). The results revealed a simple linear regression for fork length, standard length, head length, head depth, pre-dorsal (first and second) length, pre-pectoral length, pre-pelvic length, pre-anal length, body width, body depth, pectoral fin length and pelvic fin length against total length and inter-orbital width, pre-orbital length, post-orbital length, eye diameter, lower jaw length and upper jaw length against head length. The length-length relationship of morphometric parameters with each other along with its intercept (a), slope (b) and coefficient of correlation (r) are given in Table 3. The coefficient of correlation (r) of total length against other morphometric characters ranged from 0.969 (head depth) to 0.999 (fork length). Similarly, coefficient of correlation of head length against other morphometric characters ranged from 0.951 (eye diameter) to 0.994 (post-orbital length). The ' r ' value obtained indicated that the morphometric characters in the study

Table 1. Comparison of estimated parameters of the LWRs of *S. panijus* in north-western Bay of Bengal with earlier records

Authors	Location	Sex	N	Length range (cm)	Mean±S.E length (cm)	Weight range (g)	Mean±S.E weight (g)	a	CL 95% of a	b	CL 95% of b	r^2
Islam <i>et al.</i> (2012)	Meghna Estuary, Bangladesh	Pooled	30	-	28.28 ±7.30	378.22 (max)	-	-2.913	-	3.480	-	0.996
Siddik <i>et al.</i> (2015)	Ganges Delta, Bangladesh	Pooled	300	14.6-29.3	20.67±3.41	17.97-129.37	51.01±25.6	0.004	0.003-0.003	3.096	3.045-3.147	0.979
		Male	138	14.6-29.3	20.57±3.66	17.97-129.37	50.65±27.42	0.005	0.003-0.007	2.994	2.925-3.062	0.982
		Female	162	14.7-28.7	20.76±3.20	18.02-117.42	51.32±24.06	0.003	0.001-0.005	3.209	3.137-3.282	0.979
Hossain <i>et al.</i> (2015)	Tetulia River, Bangladesh	Pooled	155	17.4-34	-	27.5-248.3	-	0.0021	0.0011-0.0041	3.30	3.07-3.51	0.981
Present study (2019)	North-western Bay of Bengal along Indian coast	Male	56	11-33.2	22.92 ± 4.45	7.6-229.8	78.4± 42.17	0.0048	0.003-0.007	3.059	2.951-3.168	0.983
		Female	460	9.9-40.3	26.35± 5.43	5.8-506	127.1± 86.09	0.0032	0.003-0.004	3.185	3.141-3.230	0.977
		Indeterminate	106	7.8-26.2	14.2± 3.36	2.9-111.1	19.2± 18.3	0.0047	0.004-0.007	3.065	2.991-3.138	0.985

N : No. of samples, CL : Confidence limit

Table 2. Statistical estimates of morphometric characters (measured in cm) of *S. panijus*

Morphometric character	Range		Mean	Median	SD	SE	CV (%)
	Min	Max					
Total length (TL)	7.80	40.3	22.509	20.5	8.377	1.110	37.216
Fork length (FL)	7.60	38.4	21.668	19.6	7.998	1.059	36.913
Standard length (SL)	6.60	34.1	18.946	17.4	7.058	0.935	37.253
Head length (HL)	2.02	11.2	5.765	5.23	2.268	0.300	39.332
Head depth (HD)	0.87	5.24	2.482	2.12	1.059	0.140	42.666
Eye diameter (ED)	0.29	0.92	0.629	0.61	0.189	0.025	30.018
Pre-orbital length (PrOL)	0.79	4.29	2.402	2.25	0.930	0.123	38.741
Post-orbital length (PsOL)	0.91	5.65	2.753	2.45	1.141	0.151	41.437
Pectoral fin length (PtL)	1.29	7.86	3.8950	3.38	1.672	0.221	42.916
Pelvic fin length (PeL)	0.89	4.15	2.418	2.21	0.857	0.114	35.456
Pre-first dorsal length (PDL1)	2.29	12.06	6.425	5.93	2.491	0.330	38.770
Pre-second dorsal length (PDL2)	3.20	17.14	9.079	8.17	3.583	0.475	39.466
Pre-pectoral length (PPtL)	2.02	10.8	5.896	5.38	2.284	0.302	38.732
Pre-pelvic length (PPeL)	2.17	11.7	6.308	5.67	2.471	0.327	39.167
Pre-anal length (PAL)	3.50	20.53	10.742	9.42	4.340	0.575	40.401
Inter-orbital width (IOW)	0.32	2.04	0.974	0.89	0.422	0.056	43.272
Body width (BW)	0.82	4.78	2.496	2.17	1.152	0.153	46.152
Body depth (BD)	0.99	5.74	2.870	2.56	1.258	0.167	43.842
Mouth width (MW)	0.33	1.6	0.906	0.79	0.380	0.050	41.918
Caudal depth (CD)	0.38	2.11	1.153	1.06	0.458	0.061	39.717
Lower jaw length (LJL)	0.23	1.55	0.808	0.68	0.388	0.051	48.08
Upper jaw length (UJL)	0.36	2.11	1.064	0.98	0.476	0.063	44.74

are significantly correlated ($p < 0.01$) with each other. All the statistical estimates of the morphometric characters indicated homogeneity within the population of *S. panijus* along the north-western Bay of Bengal. The coefficient of correlation (r) of total length against other morphometric characters is more than 0.969 (towards unity) with significant relationship ($p < 0.01$) (Table 3), similar to results obtained in Bangladesh waters (Islam *et al.*, 2012; Siddik *et al.*, 2016a). The length-length relationship of *S. panijus* in north-western Bay of Bengal is described here for the first time. The fin formula with gill raker count derived from analysis of meristic counts was $D_1 X, D_2 I + 24-28, P 17-22, V I + 5, A II + 25-27, GR 2-3/6-9$.

Among all the meristic counts, the coefficient of variation was found to be maximum for upper limb of gill rakers (16.1%), followed by lower limb gill raker (8.1%) and scales below the lateral line (5.2%). The descriptive statistics for meristic counts are presented in Table 4.

The values of almost, all the meristic counts are found within the ranges provided by the earlier authors (Dutt and Sujatha, 1980; Talwar and Kacker, 1984; McKay, 1985, 1992; Rahman, 1989, 2005; Islam *et al.*, 2012; Rao *et al.*, 2013) with a different count of first dorsal fin spine - IX reported by Hamilton (1822), Day (1889) and Rahman (1989, 2005) (Table 5). Such difference in first dorsal spine count is mostly because the last spine

of the first dorsal fin is either damaged or torn out during fishing or post-harvest handling (personal observation by the first author). The morpho-meristic characters also differ in same species from different geographical areas due to the effect of genetic structure or environmental conditions (Francicevic *et al.*, 2005).

In the present study, large numbers of specimens were collected from various gears in the coastal waters of north-western Bay of Bengal by covering a wider size range (7.8-40.3 cm TL) in all the seasons for a period of one year. However, the study has certain limitations, including non-representation of smaller size classes below 7.8 cm TL, which may be due to the selectivity of the fishing gears employed rather than their absence in the fishing ground (Hossain *et al.*, 2012; Roul *et al.*, 2017). In future, sampling of individuals can be improved by collecting smaller specimens (<7.8 cm TL), smaller than the smallest individual collected in this study by a standardised sampling procedure (larval survey net) using a research survey vessel.

The present study provides significant baseline information on the morphometric, meristic, LWRs and LLRs of *S. panijus* from north-western Bay of Bengal waters. These results will be helpful for further studies towards effective fisheries management and conservation of this species in the region.

Table 3. Length-length relationship of various morphometric characters of *S. panijus*

Morphometric character	Intercept (a)	Slope (b)	Y = a + bX	Correlation coefficient (r)
Total length & Fork length	0.188	0.954	FL = 0.188 + 0.954 TL	0.999
Total length & Standard length	0.003	0.842	SL = 0.003 + 0.842 TL	0.998
Fork length & Standard length	-0.158	0.882	SL = - 0.158 + 0.882 FL	0.998
Total length & Pre-first dorsal length	-0.232	0.296	PDL1 = - 0.232 + 0.296 TL	0.995
Total length & Pre-second dorsal length	-0.498	0.426	PDL2 = - 0.498 + 0.426 TL	0.995
Total length & Pre-pectoral length	-0.209	0.271	PPtL = - 0.209 + 0.271 TL	0.995
Total length & Pre-pelvic length	-0.27	0.292	PPeL = - 0.27 + 0.292 TL	0.991
Total length & Pre-anal length	-0.878	0.5162	PAL = - 0.878 + 0.516 TL	0.996
Total length & Head length	-0.3	0.27	HL = - 0.3 + 0.27 TL	0.995
Total length & Head depth	-0.304	0.123	HD = - 0.304 + 0.124 TL	0.969
Total length & Body depth	-0.456	0.148	BD = - 0.456 + 0.148 TL	0.984
Total length & Body width	-0.521	0.134	BW = - 0.521 + 0.134 TL	0.975
Total length & Caudal depth	-0.063	0.054	CD = - 0.063 + 0.054 TL	0.988
Total length & Pectoral fin length	-0.513	0.196	PtL = - 0.513 + 0.196 TL	0.981
Total length & Pelvic fin length	0.168	0.1	PeL = 0.168 + 0.1 TL	0.977
Head length & Inter-orbital width	-0.088	0.184	IOW = - 0.088 + 0.184 HL	0.991
Head length & Mouth width	-0.024	0.161	MW = - 0.024 + 0.161 HL	0.964
Head length & Pre-orbital length	0.051	0.408	PrOL = 0.051 + 0.408 HL	0.993
Head length & Post-orbital length	-0.13	0.5	PsOL = - 0.13 + 0.5 HL	0.994
Head length & Eye diameter	0.178	0.079	ED = 0.178 + 0.079 HL	0.951
Head length & Lower jaw length	-0.146	0.165	LJL = - 0.146 + 0.165 HL	0.966
Head length & Upper jaw length	-0.119	0.205	UJL = - 0.119 + 0.205 HL	0.978

Table 4. Statistical estimates of different meristic characters of *S. panijus*

Meristic characters	Range	Mean	Median	Mode	SD	SE	CV (%)
Dorsal fin rays	IX, I + 24-28	26.0	26	26	0.9	0.12	3.5
Pectoral fin rays	17-22	20.1	20	20	1.0	0.13	4.8
Pelvic fin rays	I + 5	5	5	5	0	0	0
Anal fin rays	II + 25-27	25.6	26	26	0.5	0.07	2.1
First gill raker (Lower)	6-9	7.7	8	8	0.6	0.08	8.1
First gill raker (Upper)	2-3	2.7	3	3	0.4	0.06	16.1
Scales above lateral line	6	6	6	6	0	0	0
Scales below lateral line	13-14	12.0	12	13	0.6	0.08	5.2
Scales on lateral line	83-91	87.3	87.5	88	3.03	0.4	3.47

Table 5. Comparison of meristic counts of *S. panijus* with published literature

Meristic characters	Hamilton (1822)	Day (1889)	Dutt and Sujatha (1980)	Talwar and Kacker (1984)	McKay (1985)	McKay (1992)	Rahman (1989, 2005)	Islam <i>et al.</i> (2012)	Rao <i>et al.</i> (2013)	Present study (2019)
Specimen (n)	-	-	2	-	10	-	-	30	1	57
Dorsal fin rays	IX + 28	IX, I+25-27	X, I+27	X, I+26-27	X, I+26-27	X, I+25-27	IX, I+26-27	X, I+27-28	X, I+27	X, I+24-28
Pectoral fin rays	20	24	20-22	-	-	-	23-24	16-20	20	17-22
Pelvic fin rays	I+6	I+5	-	-	-	I+5	I+5	I+5	I+6	I+5
Anal fin rays	28	I+26-27	II+26-27	II+24-26	II+24-26	II+24-27	II+25-26	II+24-28	II+26	II+25-27
First gill raker (Lower)	-	-	7	6	-	-	-	-	-	6-9
First gill raker (Upper)	-	-	2+1	-	-	-	-	-	-	2-3
Scales above lateral line	-	5-6	4-5	-	6	-	-	6-9	-	6
Scales below lateral line	-	14	13	-	13	-	-	10-15	-	13-15
Lateral line scales	-	90	87-89	84-88	84-88	84-90	84-88	83-98	92	83-91

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