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Insights into biological parameters of *Macrognathus pancalus* (Hamilton, 1822) from the river Ganga, Bihar, India

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Abstract

Growth pattern, sex ratio, gonadosomatic index (GSI), hepatosomatic index (HIS), size at first maturity, fecundity, and ova diameter of *Macrognathus pancalus* (Hamilton, 1822) from the river Ganga were studied. A total of 450 specimens were collected from two fish landing sites namely, Digha Ghat Patipul and Fatwah Ghat, located along the river Ganga. Females ranged from 75.83 to 165.20 mm in total length (TL) with corresponding body weights of 1.47 and 17.39 g, and males ranged from 77.50 to 153.70 mm in TL, weighing between 1.05 and 10.65 g. Both sexes exhibited positive allometric growth; the allometric coefficient was slightly higher in females. Overall M: F sex ratio was 0.9:1, which did not deviate statistically from the hypothetical value of 1:1, indicating an approximately equal representation of both sexes in the population. GSI indicated bimodal spawning season, with peaks in February and August–September. Males attain sexual maturity at a smaller size and lower body weight than females. A significant positive correlation was observed between HIS and GSI ($r = 0.69$, $p<0.0001$). Mean absolute and relative fecundities were 715.17± 2.08 eggs per female and 87.34±5.08 eggs g^{-1} body weight, respectively. Eggs were spherical in shape, with a mean diameter of 1.17±0.02 mm. Fecundity appeared to increase with fish weight rather than length. These findings will be valuable for stock assessment studies of the species in this region, as well as for the conservation and sustainable management of the species.

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Introduction

Macrognathus pancalus (Hamilton, 1822) is a freshwater spiny eel that belongs to the order Synbranchiformes and family Mastacembelidae. It is a benthopelagic species commonly inhabiting shallow and slow-running rivers, estuaries, canals, streams, and wetland ecosystems (Talwar and Jhingran, 1991). It is predaceous and mainly prefers annelids, aquatic insects, crustaceans, and other organisms, including minor carp, gastropods, and aquatic vegetation (Serajuddin and Ali, 2005). Owing to its ecological significance, good consumer preference, and ornamental value, the species has attracted considerable research attention. Previous studies have focused on its taxonomy, distribution, sexual dimorphism, feeding ecology, spawning behaviour, reproductive biology, and morphometry-based body weight prediction models (Suresh *et al.,* 1972; Swarup *et al.,* 1972; Talwar and Jhingran, 1991; Serajuddin and Ali, 2005; Zahid *et al.,* 2013; Abujam and Biswas, 2020; Borah *et al.,* 2022; Ahirwal *et al.,* 2024). Length-weight relationships (LWRs) are often used to assess the growth pattern and health status of a fish. LWRs also have a wide range of applications in stock assessment models to estimate growth parameters (Froese, 2006). It also enables comparing the growth pattern of fish populations of similar species from different rivers, lotic and lentic ecosystems (Singh *et al.,* 2023; Kumar *et al.,* 2024). Knowledge on reproductive parameters such as sex ratio, gonadosomatic index, length at first maturity, spawning seasons, spawning periodicity, fecundity, and egg diameter is essential for determining the reproductive potential of a species and which provides sufficient scientific basis for rational utilisation of fish stocks (King, 1995). In Bihar, *M. pancalus* is an economically important small indigenous fish that commands a high market price (approximately US$ 6–7 kg^{-1}) owing to its excellent taste and consumer demand. In addition, its attractive body colouration and manageable size have enhanced its importance in the ornamental fish trade (Ahirwal *et al.,* 2024). Despite its ecological and economic significance, information on key biological parameters of the species remains limited. Therefore, the present study was undertaken to assess the growth pattern, sex ratio, gonadosomatic index (GSI), hepatosomatic index (HIS), size at first maturity, fecundity, and ova diameter of *M. pancalus*. The findings of the study provide baseline information that will be beneficial for future studies on its stock status in the region.

Materials and methods

A total of 450 specimens were collected from two fish landing sites namely Digha Ghat Patipul (25°40'8.4"N; 85°0'18"E) and Fatwah Ghat (25°30'50.3"N; 85°18'11.4"E) located along the river Ganga, Bihar, India, during the period January to December 2022 (Fig. 1). Freshly caught specimens were kept in an ice box and brought to the laboratory. The fish were cleaned with tap water, and their total length (mm) and body weight (g) were measured using a digital Vernier calliper (Insize–0/150) and digital balance (WENSAR TM–MAB 220), respectively.

The length-weight relationship was established separately for males and females using the equation $W= aL^b$ where, W is body weight (g), L is total length (mm), a is the intercept and b is the regression coefficient (Le-Cren, 1951). Further, the relationship was expressed in the logarithmic form as $\log W= \log a + b \log L$. ANCOVA was performed to determine variations in b values between both sexes (p=0.05). To test the deviation of b from the isometric value of 3, a student's t-test was employed, and the calculated value was compared with the t-table value for n–2 degrees of freedom (p=0.05). GSI was calculated based on the formula as per Wootton (1978): $GSI = 100 \times (G_W/B_W)$, where G_W is the weight of the gonad and B_W is the body weight of the fish. HSI was estimated using the equation $HSI = 100 \times L_W/B_W$, where L_W is the weight of the liver and B_W is the body weight of the fish (Welcomme, 2001). Based on the macroscopic appearance of gonads, maturity stages were classified as immature (stages I and II), maturing (stage III), mature

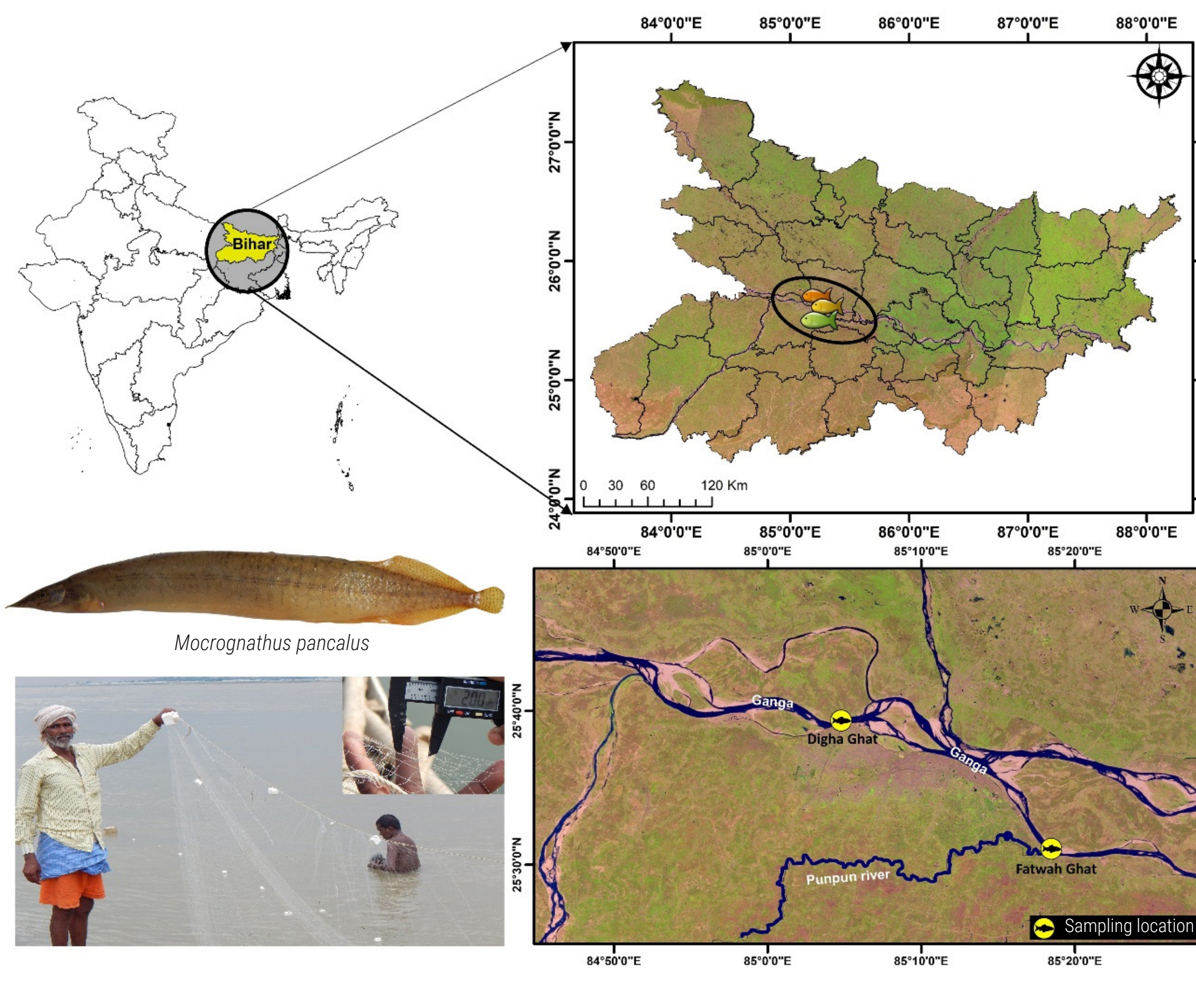

Fig. 1. Map of the sampling sites in the river Ganga

or ripe (stage IV), and spent (stage V) (Brown-Peterson *et al.,* 2010). For estimation of length at first maturity, the cumulative percentage of mature specimens (stage III onwards) was drawn against their length group at 10 mm intervals, and the length at which 50% of the population was mature was considered the length at first maturity (Hodgkiss and Mann, 1978). Fish fecundity was estimated using the formula $F = N \times (O_W/S_W)$, where N is the number of eggs in sub-sample, O_W is the ovary weight (g), and S_W is the weight of the sub-sample (g) (Grimes and Huntsman, 1980). Fecundity was determined from 31 specimens, whose total length ranged from 135.1 to 165.2 mm and weight from 9.86 to 15.25 g, respectively. The egg diameter was calculated for each mature ovary using the formula OD = (1 / n) x mm, where OD is the ova diameter, and n is the number of eggs per mm (Hickling and Rutenberge, 1936). Sex ratio was analysed using chi-square test (p=0.01 and p=0.05).

Results and discussion

The sampled fishes were caught with the help of drag net (length 150–200 m, width 4–5 m, codend mesh size 10–20 mm), monofilament drift gill net (length 100–200 m, width 1.5–2 m, mesh size 10–30 mm, operational time 4-6 h), and conical trap net/Khairel jal (length 7–8 m, mouth width 10 m, codend width 1 m, codend mesh size 5–10 mm). Total length (TL) of females varied from 75.83 to 165.20 mm, (average 116.8±1.13 mm), with weights ranging between 1.47 and 17.39 g, (average 6.795±0.21 g). Males ranged from 77.50 to 153.70 mm in TL (average 89.66±0.87 mm) with weights ranging between 1.05 and 10.65 g (average 4.113±0.11 g). Females were significantly longer and heavier than males (t = 11.03, df = 450, p<0.0001). Table 1 shows the seasonal sample size, mean length, mean weight, and regression parameters of length-weight relationships. LWRs were established as $W = 0.002 L^{3.38}$ for females and $W = 0.004 L^{3.07}$ for males. Further, the logarithmic form is also noted as Log W= -6.195 + 3.338 Log L (r^2 = 0.941) for females, and Log W= -5.561 + 3.074 Log L (r^2 = 0.857) for males.

ANCOVA showed significant difference between male and female in the value of the exponent b (p<0.05). Hence, a common equation was not derived. The estimated b-value revealed positive allometric growth in males (b = 3.07) and females (b = 3.38), while indicating comparatively greater body robustness in females. These differences in the growth pattern between sexes can be attributed to the size of the gonads. In mature female specimens, the entire body cavity is occupied by strap-shaped paired mature ovaries (length range 36.60-49.90 mm; mean length 41.26±3.86 mm) of which the right one is slightly longer than the left, whereas the testis (length range 21.30-28.80 mm; mean length 25.25±0.49 mm) in males is slender and thread-shaped. The present observations are consistent with earlier studies on *M. pancalus*, *Anguilla anguilla*, *Anguilla rostrata*, and *Macrognathus aral*, which have reported that females generally attain larger body sizes, whereas males remain comparatively smaller and slender (Suresh *et al.,* 1972; Vollestad, 1992; Cote *et al.,* 2015; Abujam and Biswas, 2020). The distribution of gonadal maturity stages across length groups demonstrated a distinct size-dependent pattern (Table 2). The proportion of immature individuals progressively declined with increasing body length, whereas the occurrence of mature and spent individuals increased in the larger length classes suggesting that gonadal development and reproductive activity are closely associated with body size. Based on the cumulative percentage of mature individuals, the size at first maturity was estimated to be 135 mm TL for females, corresponding to a mean body weight of

Table 1. Seasonal length-weight relationship parameters of *M. pancalus* from the river Ganga

Season	Female						Male					
	N	Mean L± SE	Mean W± SE	*a*	95% CL *b*	r^2	N	Mean L ± SE	Mean W ± SE	*a*	95% CL *b*	r^2
Pre-monsoon	82	118.0 ± 1.57	7.028 ± 0.29	0.004	2.80–3.22	0.95	76	109.9 ± 1.39	5.068 ± 0.18	0.008	2.42–2.99	0.91
Monsoon	53	121.5 ± 2.69	7.514 ± 0.53	0.002	3.29–3.69	0.98	85	98.94 ± 1.16	3.31 ± 0.12	0.005	2.61–3.24	0.89
Post-monsoon	99	113.4 ± 1.79	6.217 ± 0.33	0.001	3.33–3.65	0.97	56	100.6 ± 1.77	4.05 ± 1.86	0.003	2.94–3.51	0.95
Pooled data	234	116.8 ± 1.13	6.795 ± 0.21	0.002	3.27–3.49	0.97	206	89.66 ± 0.87	4.11 ± 0.11	0.005	2.99–3.24	0.93

N: No. of samples; Mean L: Length; Mean W: Weight; SE: Standard error; CL: Confidence limit; a: Constant; b: Regression coefficients; r^2: Coefficients of determinant

Table 2. Length-wise maturity stages of *M. pancalus* from the river Ganga

Length group (mm)	Male (%)				Female (%)			
	Immature	Maturing	Mature	Spent	Immature	Maturing	Mature	Spent
70-80	100.0	---	---	---	---	---	---	---
80-90	58.8	22.1	19.1	---	100.0	---	---	---
90-100	41.4	17.2	29.3	12.1	81.0	14.2	04.8	---
100-110	30.0	25.2	34.5	10.3	56.3	31.3	12.4	---
110-120	46.5	07.0	32.6	14.0	34.4	32.8	27.9	04.9
120-130	50.0	05.6	27.8	16.7	37.5	28.6	19.6	14.3
130-140	---	05.0	70.0	25.0	13.6	31.8	40.9	13.6
140-150	---	---	---	---	07.7	07.7	46.2	38.5
150-160	05.5	28.5	45.5	20.5	03.5	12.5	59.0	25.0
160-170	---	---	---	---	01.5	05.0	60.0	33.5

10.33±1.49 g, and 115 mm TL for males, corresponding to a mean body weight of 5.34±0.86 g. Thus, males attain sexual maturity at a smaller size and lower body weight than females. Observations in *M. pancalus* from an oxbow lake in the Ganga River basin and Maijan Beel/wetland of the Brahmaputra River had also indicated that males mature at a smaller length than females (Suresh *et al.*, 1972; Abujam and Biswas, 2020).

Based on the gonadosomatic Index (GSI) values, the reproductive cycle of *M. pancalus* exhibited distinct seasonal variation in both sexes (Fig. 2). Female GSI values were considerably higher than those of males throughout the study period, reaching its maximum in February (11.12±0.51); it declined sharply during March–May, and subsequently increased from June onwards to attain a secondary peak in September (7.05±0.86), followed by a gradual decline until December. Male GSI values also showed a similar trend, with relatively higher values during February and August–September and lower values during November–December. The occurrence of elevated GSI values during February and again during August–September suggests two periods of intensified gonadal development, indicating a prolonged or bimodal spawning season. Overall, the temporal variation in GSI suggests that *M. pancalus* is a seasonal breeder with peak reproductive activity occurring during late winter (February) and late monsoon/early post-monsoon (August–September). The present findings are consistent with earlier reports from different regions of India, documenting a prolonged spawning season in *M. pancalus* extending from February to September (Zahid *et al.*, 2013; Abujam and Biswas, 2020; Borah *et al.*, 2022). This similarity in spawning periodicity across geographically distinct populations suggests a relatively conservative reproductive pattern in the species.

The hepatosomatic index (HSI) exhibited seasonal patterns in both sexes of the species (Fig. 3). Female HSI values were consistently higher than those of males throughout the study period. The values were highest in February, declined sharply to a minimum during April–May, and subsequently increased from June onwards, attaining secondary peaks during September–October before declining again towards December. A significant positive correlation between GSI and HSI (r=0.69, p<0.0001) indicates a close association between liver energy reserves and gonadal development. The concurrent increase in HSI and GSI during periods of gonadal maturation suggests that hepatic reserves play a crucial role in supporting reproductive processes, while the subsequent decline in both indices likely reflects energy expenditure associated with spawning activity. Overall, these findings demonstrate that reproductive development in *M. pancalus* is closely linked to seasonal fluctuations in energy storage and utilisation.

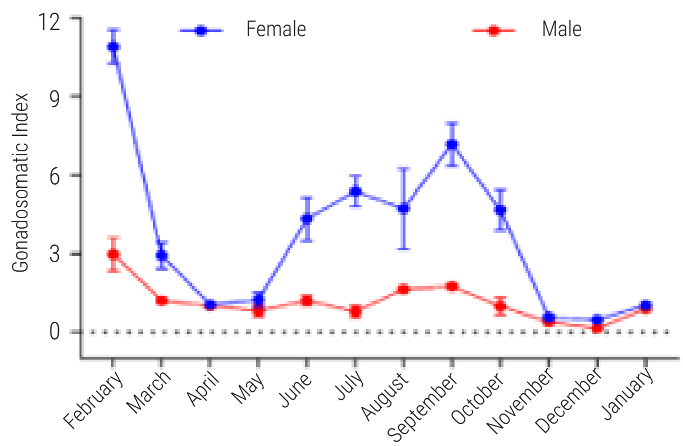

Fig. 2. GSI of male and female *M. pancalus*

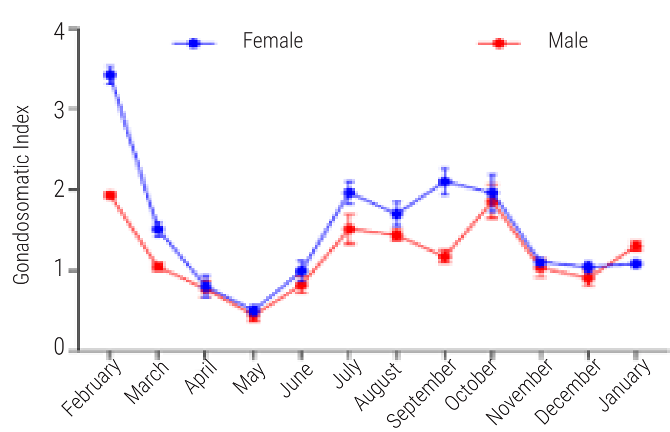

Fig. 3. HSI of male and female specimens of *M. pancalus*

The absolute fecundity varied from 219 to 1,809 eggs female^{-1}, with a mean value of 715.17±62.08 eggs female^{-1}, whereas relative fecundity ranged from 28.66 to 143.14 eggs g^{-1} body weight, averaging 87.34±5.08 eggs g^{-1} body weight. The eggs were spherical, with diameter varying from 0.92 to 1.44 mm, with an average size of 1.17±0.02 mm. The fecundity estimates obtained in the present study are comparable with earlier reports on *M. pancalus*. Suresh *et al*. (1972) reported absolute fecundity ranging from 227 to 8,310 eggs female^{-1} and relative fecundity from 45 to 274 eggs g^{-1} body weight in individuals measuring 107–170 mm in length and weighing 5.03–30.31 g. Similarly, Abujam and Biswas (2020) documented absolute fecundity ranging from 765 to 1,691 eggs female^{-1} and relative fecundity from 57 to 152 eggs g^{-1} body weight in fish with lengths of 117–145 mm and body weights of 5.70–14.18 g. The observed variation in fecundity among studies may be attributed to differences in fish size, body weight, environmental conditions, food availability, and geographic location, which are recognised as important determinants of fecundity in fishes (Nikolsky, 1963; Bagenal, 1978).

Linear regression between fecundity, total length, and total weight (Fig. 4-5) indicated that fecundity increased with fish weight rather than length, as the regression coefficient value showed a better relationship between fish weight and fecundity (r=0.84) than length and fecundity (r=0.77). This implies that heavier females will produce more eggs. Similar results were observed in earlier studies on *M. pancalus*, where fecundity had a stronger correlation with body weight than body length (Suresh *et al.,* 1972).

Table 3 shows the month-wise sex ratio of the species. Females predominated during February, June, October, November, December, and January, whereas males were more abundant during March, May, August, and September. Significant deviations from the expected

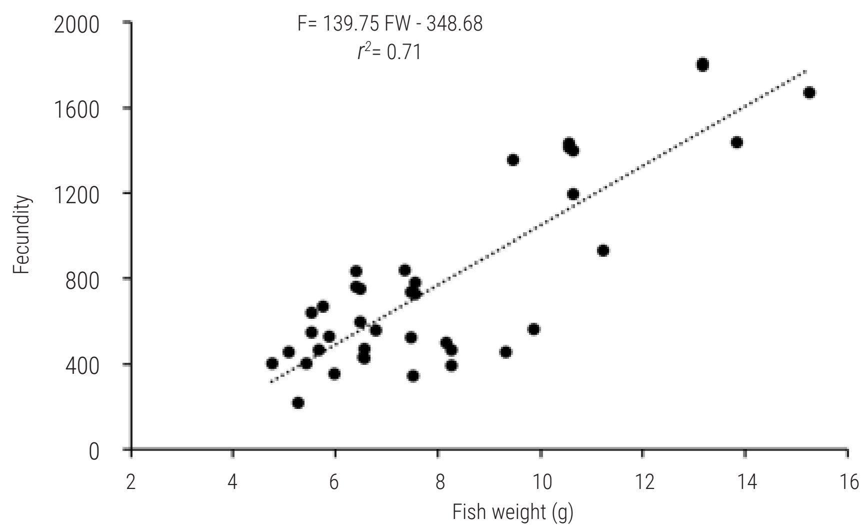

Fig. 4. Linear relationship between fecundity and fish weight of *M. pancalus*

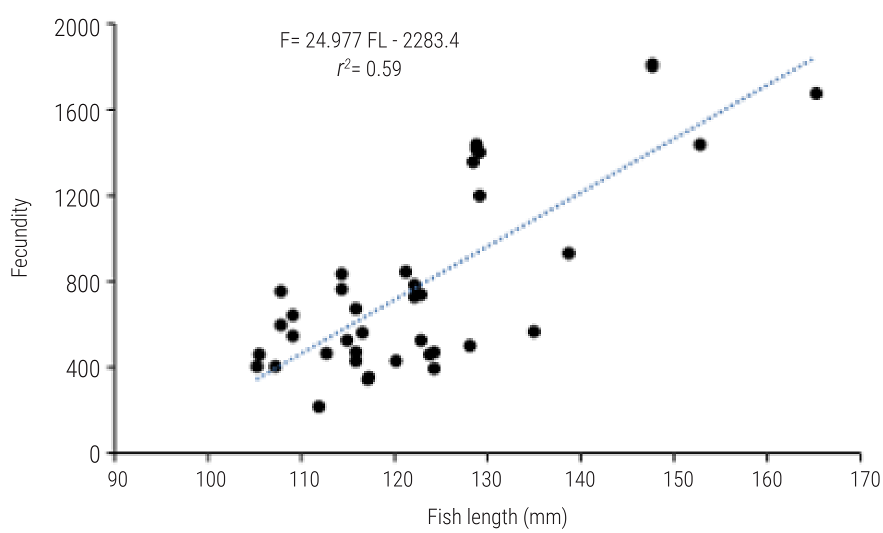

Fig. 5. Linear relationship between fecundity and fish length of *M. pancalus*

Table 3. Month-wise sex ratio parameters of *M.s pancalus* from the river Ganga

Months	Total	% of Males	% of Females	Sex ratio (M: F)	Chi Sq.
February	34	08.82	91.18	0.10:1	23.06**
March	50	60.00	40.00	1.50:1	2.00
April	43	44.19	55.81	0.79:1	0.58
May	17	58.82	41.18	1.43:1	0.53
June	28	39.29	60.71	0.65:1	1.29
July	22	45.45	54.55	0.83:1	0.18
August	46	71.74	28.26	2.54:1	8.70*
September	44	75.00	25.00	3.00:1	11.0*
October	30	43.33	56.67	0.76:1	0.53
November	54	40.74	59.26	0.69:1	1.85
December	39	23.08	76.92	0.30:1	11.31*
January	33	39.39	60.61	0.65:1	1.48
Overall sex ratio				0.90:1	1.78

*Significant ($p<0.05$) **Significant ($p<0.01$)

1:1 sex ratio were observed in February, August, September, and December. However, the overall sex ratio (M: F) was 0.90:1, which did not differ significantly from the expected 1:1 ratio, suggesting an approximately balanced sex composition in the population. The overall sex ratio observed in the present study is consistent with the findings of Swarup *et al.* (1972), who reported an approximately equal proportion of males and females in Ramgarh Lake. In contrast, studies conducted in the oxbow lakes of the Ganga River basin and the Gomati River reported a female-biased sex ratio, whereas a male-biased sex ratio was documented from the Maijan wetland (Suresh *et al.,* 1972; Zahid *et al.,* 2013; Abujam and Biswas, 2020). Such variations in sex ratio among populations may be attributed to differences in environmental conditions, habitat characteristics, sampling strategies, and fishing pressure.

M. pancalus is an ecologically and economically important small indigenous fish species of Bihar's freshwater ecosystems. Besides supporting local fisheries and rural livelihoods, the species contributes to the ecological stability of wetlands and riverine habitats. Owing to its good consumer preference, nutritional value, and local market demand, the species also possesses considerable socioeconomic importance, particularly for small-scale and subsistence fisheries. Despite this, scientific information on the species remains limited in Bihar. Although the present study provides baseline information on the growth and reproductive biology that will be useful for future research on its population dynamics, feeding ecology and stock assessment from the region.

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