



Original article

Assessing reproductive biology of *Macrobrachium lamarrei* in the Ganges River (NW Bangladesh) in relation to environmental parameters

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ABSTRACT

Macrobrachium lamarrei (H. Milne-Edwards, 1837) is a well-known freshwater prawn species of Bangladesh. The aim of the research is to explore various reproductive aspects (size at sexual maturity, reproductive period and fecundity) of *M. lamarrei* in the Ganges River, Bangladesh through October 2012 to September 2013. We also study the environmental parameters and their impact on reproduction of *M. lamarrei*. A total 391 (ovigerous = 141, non-ovigerous = 250) female specimens were collected using Drag net. The TL_{50} (the TL at which 50% of individuals become mature) was calculated by a logistic equation as 5.20 cm. Based on the availability of ovigerous females the spawning season was February–November with the peak June–July. Further, 50% and 90% ovigerous females were observed when Fulton's condition factor (K_F) was 0.85 and 1.03, respectively. The total fecundity (F_T) was ranged from 65 to 370 where TL was 4.20–6.40 cm and BW was 0.84–2.50 g. Fecundity was found to be highly correlated with TL ($r^2 \geq 0.96$, $r_s = 0.96$, $p < 0.0001$) and BW ($r^2 \geq 0.88$, $r_s = 0.93$, $p < 0.0001$). Temperature ($r_p = 0.82$, $p = 0.009$), dissolved oxygen (DO) ($r_p = -0.83$, $p = 0.0007$), pH ($r_p = 0.80$, $p = 0.0014$) and total alkalinity ($r_p = -0.87$, $p = 0.0002$), were highly correlated with ovigerous females. The average temperature on peak spawning season was 32 °C. Also, the spawning period connected with the peak rainfall and showed a notable relation between rainfall and ovigerous females. In addition, exploration of long data series pointed that yearly average air temperature is rising by 0.029 °C yr⁻¹, whereas yearly average rainfall is falling by 2.96 mm yr⁻¹. Therefore, the result will be helpful for the sustainable management and conservation of *M. lamarrei* through fixed permissible mesh size and establishment of a ban period in the Ganges River, Bangladesh and adjoining ecosystems.

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1. Introduction

Macrobrachium is one of the most mosaic freshwater genera under the family Palaemonidae. Among the crustacean fishery Palaemonidae is considered as a highly significant commercial resource worldwide (Mantelatto and Barbosa, 2005; De Grave and Franssen, 2011; Hossain et al., 2012a; Ara et al., 2014; Molina et al., 2020). *Macrobrachium lamarrei* is a member of this family

that has a lucrative significance due to its rapid growth, succinct life span and is an extremely important part of the catch nature in Bangladesh (Sharma and Subba, 2005). Amongst several freshwater prawns existing in Bangladesh, *M. lamarrei* is renowned one, usually called as “Kuncho river prawn” which is an important source of foreign exchange (Ara et al., 2014). It is also known as Kuncho chingri in India (Sharma and Subba, 2005). This kuncho river prawn is distributed in Bangladesh, India, Pakistan, and Nepal (Sharma and Subba, 2005; Ara et al., 2014). It is usually found in beels, rivers and ponds (Kibria, 1983; Ara et al., 2014). This prawn is omnivorous and feeds on all kinds of sustenance, living or dead such as micro-plankton, algae, fish fleshes, decomposing plants and animals (Sharma and Subba, 2005). *M. lamarrei* is considered a least concern species in both Bangladesh (IUCN Bangladesh, 2015) and worldwide (IUCN, 2020). Kuncho chingri comprises huge economic importance as it has better taste, high price, and growing demand in the global market (Hussain and Manohar,

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2016). Prawns are a key source of protein after fish and play a significant role in the aquatic ecosystems by reprocessing dead organic substance (Raghunathan and Valarmathi, 2005). But the production of the prawn is deteriorating owing to use of pesticides in crop fields and habitat damage. So, it is important to increase the production potentiality of this species. Therefore, an exhaustive study of reproductive biology of this prawn is needed (Sarkar et al. 2012a).

Mainly fisheries management depends on precise assessment of biological parameters (Tracey et al., 2007). Appropriate management systems for protection of the aquatic organisms are mostly relying on the information of reproductive criterion (Hardie et al., 2007). Reproductive criteria are an essential apparatus to have idea about systems of biological conservation of an aquatic organism (Hussain and Manohar, 2016).

In the mating process of *Macrobrachium* sp., the male deposits sperm on the underside of the female thorax between the walking legs. The female extrudes the eggs that pass through the sperm. The female brings the fertilized eggs with her before they are hatched; the period may vary but is usually less than three weeks (Wynne, 2000). In the natural environment, *Macrobrachium* sp. may spawn 3 to 4 times per year (Ling, 1969) or more than 4 times (Rao, 1991).

The size of maturity in fishes may vary across population from environmental condition and can help to determine the smallest catchable size of fishes as well as find out the reason for variations of maturity size (Templeman, 1987; Lucifora et al., 1999; Hasan et al., 2021; Mawa et al., 2021). Estimation of spawning/breeding season in fish is essential mainly for the conservation of mature individuals from heavy fishing pressure or other reasons (Templeman, 1987).

Fecundity is defined as the number of oocytes released from female pleopods in a single spawning season (Ramirez-Llodra, 2002). To well-understanding of the population dynamics, the information of fecundity is needed (Lagler, 1956). It is very essen-

tial for assessment of reproductive potential and providing information about the number of recruits produced in a period and the reproductive capability of the species (Hussain and Manohar, 2016; Sabbir et al., 2021). In the management strategies of prawn hatcheries, it is used to evaluate the reproductive capacity of brood prawns (Sharma and Subba, 2005).

Worldwide climate alteration responsible for the changing of aquatic ecosystem facilities those are essential for human welfare (Lorenzo and Galassi, 2017). Climate change puts extra stress on freshwater ecosystems (water quality, flow regime, and food web) interactions that have previously been seriously stressed by human activities (Doll et al., 2009; Sarkar et al., 2019). The dispersal limits of the maximum benthic organisms are distinguished by various environmental factors stand-in their whole life cycles (Bertini et al., 2010). Environmental issues (temperature and rainfall) and hydrological parameters (e.g. Do, pH, and alkalinity) have continuous effects on growth and reproduction of aquatic organisms ((Lappalainen et al., 2008; Shoji et al., 2011; Britton et al., 2013). In addition, the growth rate of aquatic organisms is reduced with the decrease of water temperature (Blanck and Lamouroux, 2007; Lappalainen et al., 2008; Carmona-Catot et al., 2011). The temperature is considered as the key to control every phase of reproduction (Pankhurst and Porter, 2003). Besides, temperature is the basic abiotic factor regulating the movements of larvae of fish and crustacean (Jakobsen et al., 2009).

Knowledge about the reproductive feature of *M. lamarrei* is scarce in the scientific papers. There are some works that have been done on various aspects for *Macrobrachium* species in water bodies worldwide (Table 1). Hence, it is the first study in which investigates the effect of environmental variation and hydrological parameters on the reproduction of *M. lamarrei* in Ganges River or anywhere else in the world. Consequently, the goal of this study is to investigate different reproductive features of *M. lamarrei* and the impact of environmental variation on their reproductive activities in the Ganges River, (NW) Bangladesh.

Table 1

Available works on *Macrobrachium* species from worldwide water bodies.

Aspect	Water bodies/country	Species	References
Growth	India Bhopal	<i>Macrobrachium malcolmsonii</i> <i>Macrobrachium lamarrei</i>	Kanaujia et al. (1997) Hussain et al. (2017)
Condition factor and length-weight relationship	Indus River	<i>Macrobrachium malcolmsonii</i>	Soomro et al. (2012)
Fish Biology	Bangladesh Godavari and Hooghle River Biratnagar, Nepal Bangladesh	<i>Macrobrachium lamarrei</i> <i>Macrobrachium malcolmsonii</i> <i>Macrobrachium lamarrei</i> <i>Macrobrachium lamarrei</i> , <i>Macrobrachium malcolmsonii</i> , <i>Macrobrachium dolichodactylus</i> and <i>Macrobrachium dayanum</i>	Ara et al. (2014) Rajyalashmi (1980) Sharma and Subba (2005) Saifullah et al. (2005)
Life history	Ganga River	<i>Macrobrachium malcolmsonii</i>	Hossain et al. (2012a)
Reproductive biology	Sao Sebastiao, Brazil Ganga River	<i>Macrobrachium olfersi</i> <i>Macrobrachium gangeticum</i> and <i>Macrobrachium malcolmsonii</i>	Mossolin and Bueno (2002) Prasad and Kanaujia (2006)
	Egypt West Bengal, India India Upper Lake at Bhopal Upper Lake at Bhopal Grande River	<i>Macrobrachium rosenbergii</i> <i>Macrobrachium dayanum</i> <i>Macrobrachium malcolmsonii</i> <i>Macrobrachium lamarrei</i> <i>Macrobrachium lamarrei</i> <i>Macrobrachium amazonicum</i>	Habashy (2010) Sarkar et al. (2012b) Mukheerjee et al. (2015) Hussain and Manohar (2016) Hussain and Manohar (2017) Paschoal et al. (2019)
Fecundity	Bangalore, South India Bangladesh Santa Catarina Island, Brazil	<i>Macrobrachium lamarrei</i> <i>Macrobrachium lamarrei</i> <i>Macrobrachium potiana</i> and <i>M. olfersi</i>	Shakuntala (1977) Paul (2001) Nazari et al. (2003)
	Bangladesh Bangladesh	<i>Macrobrachium lamarrei</i> <i>Macrobrachium</i> sp. (<i>M. rosenbergii</i> , <i>M. malcolmsonii</i> and <i>M. lamarrei</i>)	Bhuiyan et al. (2008) Rashid et al. (2013)
Population Dynamics	Tropical reservoir, India	<i>Macrobrachium malcolmsonii</i>	Khan et al. (2009)
First record	Gujarat, India	<i>Macrobrachium lamarrei</i>	Purohit and Vachhrajani (2018)

2. Materials and method

2.1. Sampling

Our research was conducted in the Ganges River (Latitude 24° 22' N; Longitude 88° 35' E), NW Bangladesh (Fig. 1). Monthly samples of *M. lamarrei* were collected from the fisher's catch landed at different points of the Ganges River (Godagari, Jahajghat, Chorghat), Rajshahi, NW Bangladesh during the sampling period (October 2012 to September 2013). The prawns were caught during

daytime 9:30 to 11:30 am using Drag net (2 mm) from different fishing points between mentioned areas.

2.2. Prawn measurement

A total 391 (ovigerous = 141, non-ovigerous = 250) specimens were collected from the study site and then fixed in 10% formalin. The fixed specimens were then taken out one by one, later to be weighed, measured and sexes were identified by the presence and absence of appendix masculina on 2nd pleopod (Tiwari,

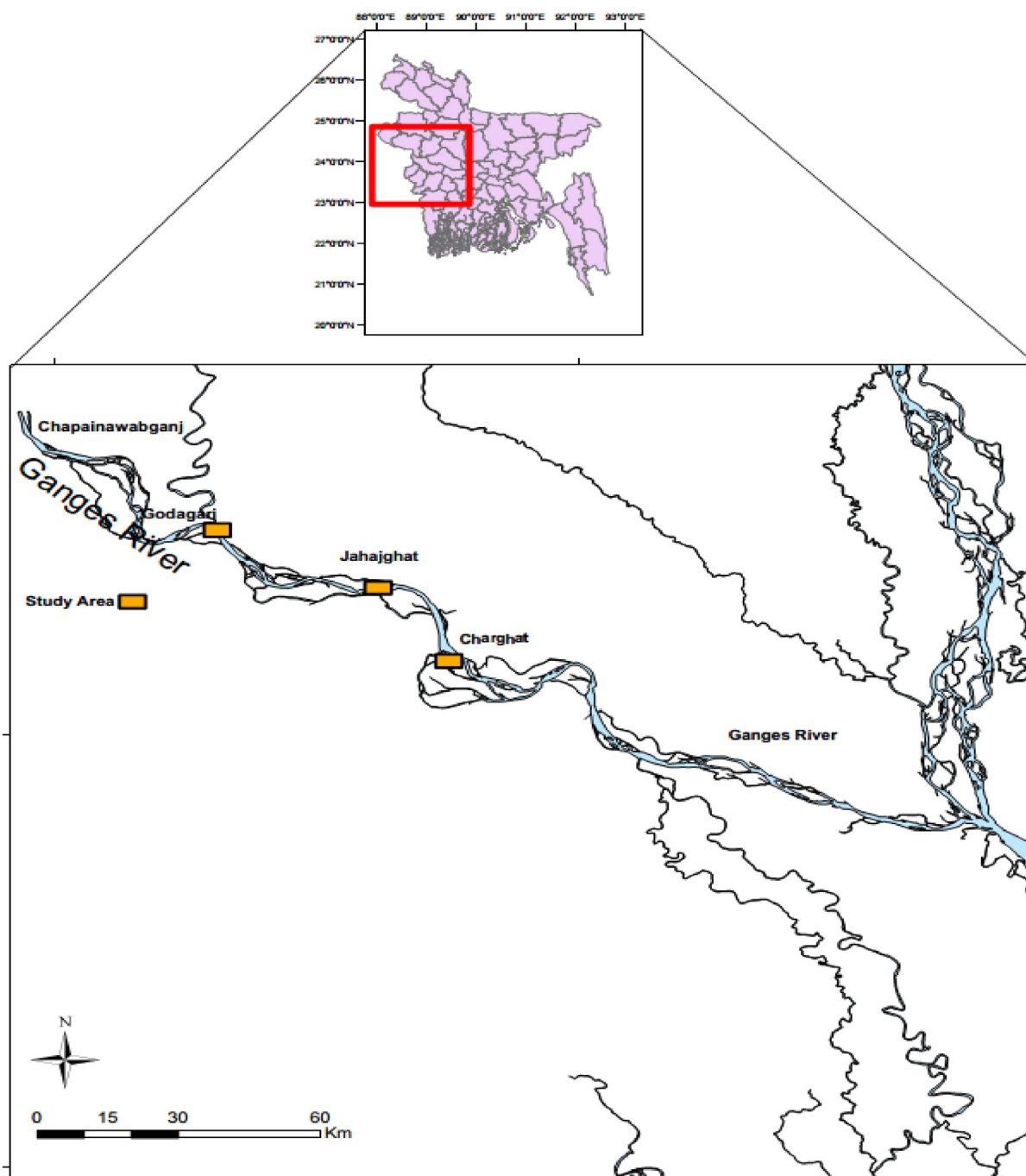


Fig. 1. The study site in the Ganges River, northwestern Bangladesh. The area from where *Macrobrachium lamarrei* was collected is indicated by rectangle.

1955; Cai and Naiyaneter, 2004). Individual total length (TL) was noted up to 0.01 cm using a digital slide caliper and weight was measured (BW, nearest 0.01 g) using an electric balance.

2.3. Size at first sexual maturity

Ovigerous females were pointed out by the bearing of embryos (external oocytes) attached on its pleopods. TL_{50} denoted the length wherein 50% of the individual specimens were matured. In order to analysis of TL_{50} , a logistic curve was applied by plotting the percentage of ovigerous female (POF) against TL class as $POF = 100/[1 + \exp\{-f(TL_m - TL_{50})\}]$ (King, 2007).

2.4. Spawning season and condition

The percentage occurrence of monthly ovigerous females was observed for estimation of spawning and peak spawning season of *M. lamarrei*. And K_F was used to assess the relationship between POF and K_F by logistic model (King, 2007). And K_F was calculated by: $K_F = 100 \times (W/L^3)$ (Fulton, 1904).

2.5. Fecundity

Firstly, forceps was used to eradicate the ovum mass from the female's brood sack and then count the number of oocytes. The fecundity was estimated by actual counting method of (Lagler et al., 1967). Relationship between (i) TL vs. F_T and (ii) BW vs. F_T were estimated by the formula: (i) $\ln F_T = m + n \ln TL$; $F_T = m \times TL^n$ and (ii) $\ln F_T = m + n \ln BW$; $F_T = m \times BW^n$. Where, F_T means total fecundity, m and n is constant parameters in the linear regression analysis. The coefficient of determination (r^2) of each of the relationships was also estimated.

2.6. Climato-hydrological parameters

Hydrological data were collected in every month from sampling station by HACH (HQ40d) digital multi-meter parameter to assess dissolved oxygen (mg/l), temperature ($^{\circ}C$), pH, total dissolved solids (TDS) mg/l and total alkalinity (mg/l). Climatological data (rainfall and air temperature) were obtained from the meteorological station of Dhaka, Bangladesh.

2.7. Statistical analyses

Statistical analyses were prepared by Past 4.03, Excel program and Graphpad Prism 6.5 with 5% significant level. Normality of the data was confirmed by Shapiro-Wilk normality test, and violin-box plot. Besides, Spearman rank test was performed to assess the relationship between POF and K_F . Pearson correlation and Spearman rank test used to evaluate the impact of the environmental and hydrological factors on POF for detecting the vital influence of environment on ovigerous female and spawning.

Table 2

Descriptive statistics on the total length (cm), body weight (g) and egg weight (g) measurements of *Macrobrachium lamarrei* in the Ganges River.

Characters	Mean \pm SD	95 %CI	Min	Max	n
Total length TL (cm)	5.11 \pm 0.49	5.06–5.16	2.80	6.40	391
Body weight BW (g)	1.10 \pm 0.33	1.06–1.12	0.22	2.50	
Egg weight EW (g)	0.11 \pm 0.05	0.09–0.12	0.05	0.30	52

n, sample size; Min, minimum; Max, maximum, SD, standard deviation; CI, confidence intervals.

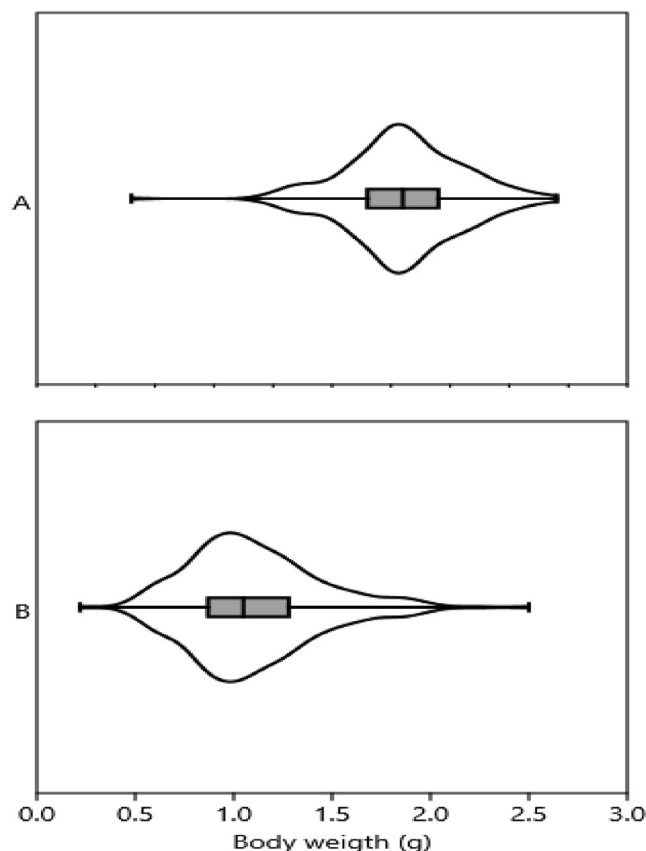


Fig. 2. Checking the normality of data (A) total length and (B) body weight of *Macrobrachium lamarrei* in the Ganges River (Data comes from a normal distribution, the box will be symmetrical with the mean and median in the center. If the data meets the assumption of normality, there should also be few outliers).

3. Results

A total 391 (ovigerous = 141, non-ovigerous = 250) female specimens of *M. lamarrei* were analyzed, total length was ranged from 2.80 to 6.40 cm, body weight was 0.22–2.50 g and egg weight was 0.05–0.30 g (Table 2). Data (TL, BW) did not pass the normality ($p < 0.0001$, Fig. 2).

3.1. Size at first sexual maturity

According to the logistic model, the size at sexual maturity of *M. lamarrei* (L_m) was 5.20 cm (Fig. 3).

3.2. Spawning season and condition

Monthly changes in POF were recorded (Fig. 4). Ovigerous females were found from February–November with the highest percentage in June–July. No ovigerous female was observed during December 2012 to January 2013. So, the spawning season of *M. lamarrei* was February–November and the peak was in June–July.

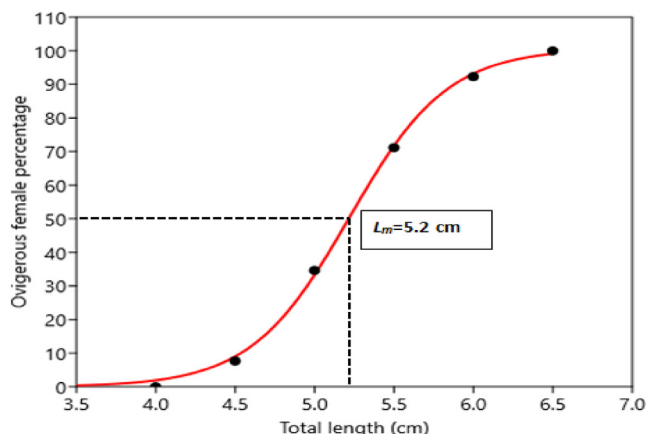


Fig. 3. Adjusted percentage of mature females of *Macrobrachium lamarrei* versus total length showing the logistic curve fitted to the data.

sp. from world-wide water bodies and fishes in Ganges River was given in Table 3.

3.3. Fecundity indices

For the calculation of fecundity (F_T), a total of 52 females (4.20–6.40 cm TL) were used. F_T ranged from 65 to 370 (mean \pm SD, 154 ± 59). Significant correlation observed between total fecundity vs. total length ($r^2 \geq 0.96$, $r_s = 0.96$, $p < 0.0001$) and total fecundity vs. body weight ($r^2 \geq 0.88$, $r_s = 0.93$, $p < 0.0001$). The relative fecundity ranged from 76 to 163 (mean 128 ± 19). Also, significant linear relationships were found for natural log (ln) transfer of F_T - TL, F_T - BW. Above relationships were shown in (Fig. 6).

3.4. Climato-hydrological parameters

In this study, according to Pearson correlation test, temperature ($r_p = 0.828$, $p = 0.009$), dissolved oxygen (DO) ($r_p = -0.83$,

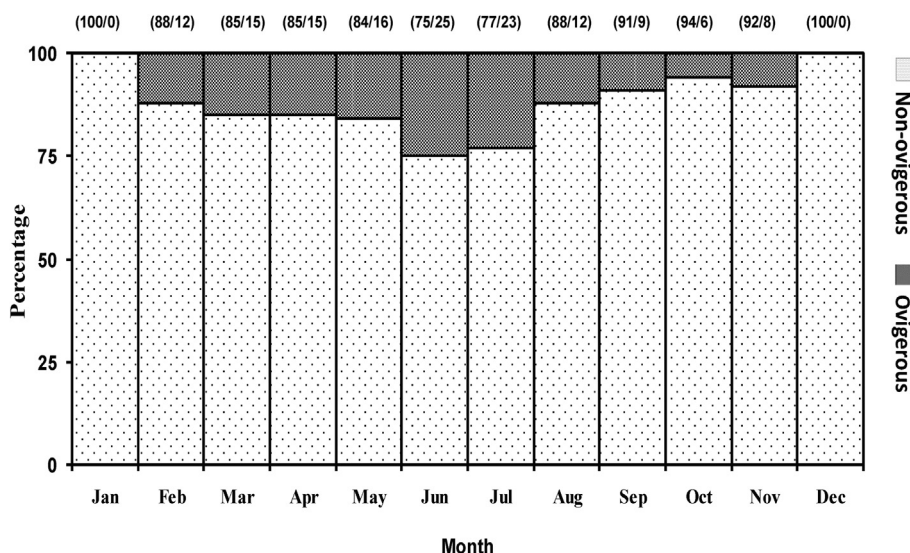


Fig. 4. Monthly changes in percentage occurrence of ovigerous and non-ovigerous females of *Macrobrachium lamarrei* in the Ganges River. The number of females examined in each month is given in parentheses.

According to the logistic model 50% ovigerous females were found when K_F was 0.85 and 90% ovigerous females were found when K_F was 1.03 (Fig. 5). In addition, spawning season of *Macrobrachium*

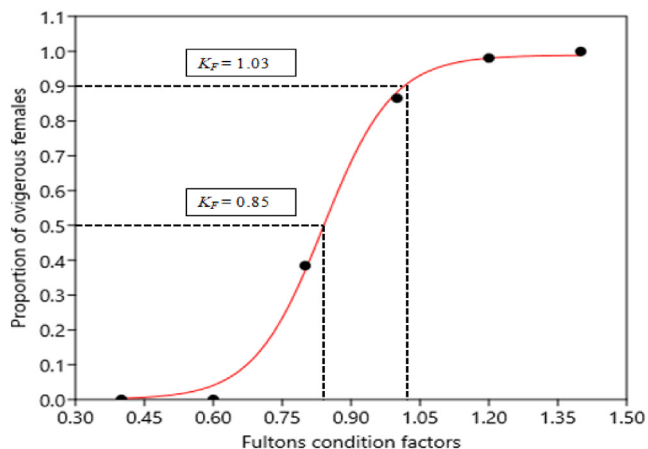


Fig. 5. Adjusted percentage of mature females of *Macrobrachium lamarrei* versus Fulton's condition factor showing the logistic curve fitted to the data.

$p = 0.0007$), pH ($r_p = 0.80$, $p = 0.0014$) and total alkalinity ($r_p = -0.87$, $p = 0.0002$), were highly correlated with ovigerous females except TDS ($r_p = -0.43$, $p = 0.1606$) (Table 4, Fig. 7). In April–July, we observed the highest water temperature (average 32 °C) when an ovigerous female was in elevation. The lowest temperature was in January and this time no ovigerous females were absent.

A long data series (1964 to 2014) of air temperature and of rainfall were arranged to observe its fluctuation over time. The yearly average air temperature was rising up to $0.029 \text{ }^\circ\text{C yr}^{-1}$ ($r^2 = 0.350$) while rainfall indicated dropping trend by 2.96 mm yr^{-1} ($r^2 = 0.018$) (Fig. 8). However, air temperature ($r_s = 0.8248$, $p = 0.0015$) and rainfall ($r_s = 0.6925$, $p = 0.0152$) was recorded significantly related with POF (Fig. 9).

4. Discussion

Information on reproductive features is vital to assess the life cycle and stocks of fish as well as aquatic organisms (Hossain et al., 2017). Our research presents the most comprehensive investigation on reproductive biology of *M. lamarrei*. The L_m is an essential tool for fisheries management and planning (Lucifora et al.,

Table 3
Spawning season of *Macrobrachium* species from worldwide water bodies and fishes from the Ganges River.

Water bodies	Species	Spawning season	Peak spawning season	Reference
Bangladesh	<i>Macrobrachium lamarrei</i>	May-August	–	Paul (2001)
Sao Sebastiao, Brazil	<i>Macrobrachium olfersi</i>	Continuous	Warmer and rainy months	Mossolin and Bueno (2002)
Biratnagar, Nepal	<i>Macrobrachium lamarrei</i>	March–November	–	Sharma and Subba (2005)
Upper Lake, Bhopal	<i>Macrobrachium lamarrei</i>	Continuous	June and November	Hussain and Manohar (2016)
Ganga River	<i>Macrobrachium malcolmsonii</i>	Continuous	August and September	Prasad and Kanaujia (2006)
Bangladesh	<i>Macrobrachium lamarrei</i>	April–June	–	Bhuiyan et al. (2008)
West Bengal	<i>Macrobrachium lamarrei</i>	Continuous	–	Sarkar et al. (2012b)
Upper Lake, Bhopal	<i>Macrobrachium lamarrei</i>	Continuous	May– June and November – December	Hussain and Manohar (2017)
Grande River	<i>Macrobrachium amazonicum</i>	Continuous	–	Paschoal et al. (2019)
Ganga River	<i>Macrobrachium lamarrei</i>	February–November	June–July	Present study
Habitat/River	Species	Spawning season	Peak spawning season	Reference
Ganges	<i>Channa punctatus</i>	June - October	–	Prasad et al. (2011)
Ganges	<i>Rita rita</i>	May -September	July and September	Alam et al. (2016)
Ganges/Padma	<i>Mystus vittatus</i>	March -September	June	Jasmine and Molina (2016)
Ganges	<i>Ompok bimaculatus</i>	June–August	July	Praveen et al. (2017)
Ganges/Padma	<i>Eutropiichthys vacha</i>	April– August	June–July	Khatun et al. (2019)

1999; Hossain et al., 2012b; 2013; 2016). In the present study, the L_m was 5.02 cm (TL) for *M. lamarrei*. Whereas, Hussain and Manohar (2017) reported the L_m was 4.70 cm (TL) from the upper lake Bhopal, India which is lower than our results. However, L_m may vary due to population thickness, water temperature, perceived length and food availability (Hossain et al., 2012c).

Reproduction cycle and time of spawning was estimated by several models including direct observation of spawning, brooding of eggs over time, appearance of ovary and maturation stages over time (King, 2007), relative weight of gonad (TL vs. gonadosomatic index, modified gonadosomatic index and dobrial index) over time (Hossain et al., 2017; Ahamed et al., 2018; Khatun et al., 2019; Sabbir et al., 2021) and histological studies (Chelemal et al., 2009; Hussain and Manohar, 2017; Lucano-Ramírez et al., 2019). The spawning seasons of *M. lamarrei* was estimated by the percentage of mature females present in the catch or by changes in gonadal indices (Garcia, 1985; Erisman et al., 2012). However, in the current study we observed that the ovigerous females of *M. lamarrei* were found throughout the year except the month of December and January which means the spawning season was February–November with the peak of June and July. Sharma and Subba (2005) reported that females of *M. lamarrei* were not having mature eggs in the month of December, January and February from Biratnagar, Nepal which is close agreement with our present study. Hussain and Manohar (2016, 2017) and Sarkar et al. (2012b) reported that *M. lamarrei* was a continuous breeder from Bhopal and West Bengal in India respectively, which is also almost similar to our findings. Whereas, Bhuiyan et al. (2008) recorded spawning season was April–June from Rajshahi, Bangladesh and Paul (2001) reported May–August from Natore, Bangladesh which is dissimilar to our present study. Hussain and Manohar (2016, 2017) reported two peak seasons (May–June and November–December) in a year for *M. lamarrei* from Bhopal, India. However, this disparity may be occurring due to environmental factors, population densities, and food availability (Khatun et al., 2019; Sabbir et al., 2021).

Condition factor discloses several biological interfaces of aquatic organisms like maturity status and level of fitness (Hossen et al., 2019; Sabbir et al., 2020). In this study, K_F was found significantly related to POF and our observed K_F range was 0.85–1.03 which is suitable for the spawning of *M. lamarrei*.

Fecundity is used for predicting how many of broods are requisite to producing preferred quantities of offspring (Sharma and Subba, 2005). In addition, it helps to estimate the smallest number of broods needed to sustain the recruitment and offspring survival rates. In the present study, the F_T of *M. lamarrei* varied from 65 to 370 (154 ± 59). Saifullah et al. (2005) documented the total fecundity (F_T) ranged from 141 to 328 in the North East and North West

regions, Bangladesh. Likewise, Shafi and Quddus (1982), Sharma and Subba (2005), Hussain and Manohar (2016) recorded fecundity was ranged from 2250 to 16300, 82–308, and 69–143 in Biratnagar, Nepal, Bhopal, India and Bangladesh respectively. However, the numbers of eggs for many crustaceans' species are highly variable (Khmeleva and Golobev, 1986). This variation occurs due to some factor i.e. age, length, weight and environmental condition (Sharma and Subba, 2005).

The success of crustaceans can be ascribed to the point that most of them bear their ovum till hatching and this is why offspring survival rate is high. The sizes of the mother control the number of ovum/egg carried by a female. In numerous crustaceans, the number of eggs has been observed to be linear to the size of the female (Vogt, 2012; Subramoniam, 2013). In addition, in the current study we observed that the total fecundity (F_T) has significant relationship with TL and BW which was supported by Saifullah et al. (2005). Whereas, Sharma and Subba (2005) observed insignificant relationship between total length and total fecundity which was dissimilar with our findings and significant relationship between body weight and total fecundity which was support our present findings.

The impact of environmental change on aquatic organisms will differ with habitat, latitude, water features, and in riverine schemes, current regimes (Pankhurst and Munday, 2011). Globally, in the current years it has been reported that freshwater aquatic species could change their distribution in response to climate change (Sarkar et al., 2019). The reproductive strategy of *M. lamarrei* was affected by the environmental conditions. In our study, the peak values of ovigerous females (%) followed from June–July and at the same time water temperature is also high which confirms that water temperature has an effect on prawn reproduction. During our study, the lowest temperature was found in January, and the highest was in April–June and there was substantial connection between temperature and ovigerous females. The spawning period was started when temperature is above than 25 °C. In this study, the highest ovigerous female (%) was observed when the average temperature was 32 °C. In case of *Macrobrachium rosenbergii* suitable temperature for spawning was 25–29.5 °C under a laboratory condition in Egypt recorded by Habashy (2010). We found DO, pH and total alkalinity ranges around 5.52–6.10 mg/l, 7.13 and 82.14–90.90 mg/l, respectively from peak spawning time of *M. lamarrei*. So, these ranges are supposed to be optimum for reproduction of *M. lamarrei*. There was no work on these types for *M. lamarrei* but Habashy (2010) research on these aspect for *M. rosenbergii* and found suitable ranges DO and pH was 6.00–6.80 mg/l and 7.5–8.4, respectively from Egypt (under a laboratory condition). The analysis of climate data (1964–2014) indicated temperature

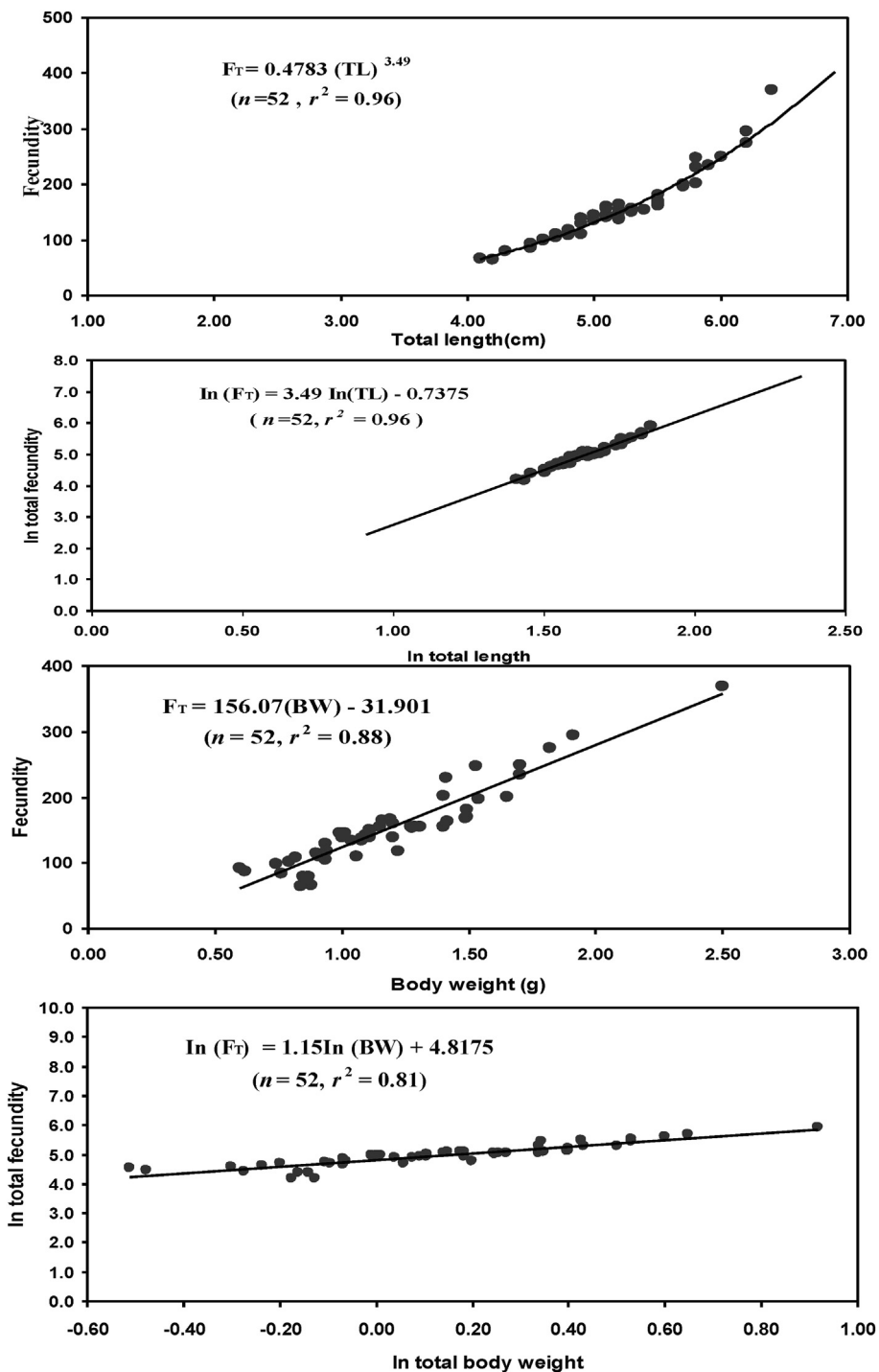


Fig. 6. The relationships between (i) total length vs. fecundity (ii) body weight vs. fecundity (iii) ln total length vs. ln fecundity (iv) ln body weight vs. ln fecundity of *Macrobrachium lamarrei* in the Ganges River.

Table 4

Relationship between hydrological parameters with Oviparous female of *Macrobrachium lamarrei* (H. Milne-Edwards, 1837) in the Ganges River.

Relationship	r_s value	95% CL of r_s	p values	Significance
GSI vs. Temperature	0.82	0.48 to 0.95	0.0009	*
GSI vs. DO	-0.83	-0.95 to -0.50	0.0007	*
GSI vs. p^H	0.80	-0.44 to 0.94	0.0014	*
GSI vs. TDS	-0.43	-0.80 to 0.18	0.1606	ns
GSI vs. Total alkalinity	-0.87	-0.96 to -0.60	0.0002	*

GSI, Gonadosomatic index; DO, Dissolved Oxygen; TDS, Total Dissolved Solids; r_s , Spearman rank correlation values; CL, confidence limit; p , shows the level of significance; ns, not significant; * significant ($p \leq 0.05$).

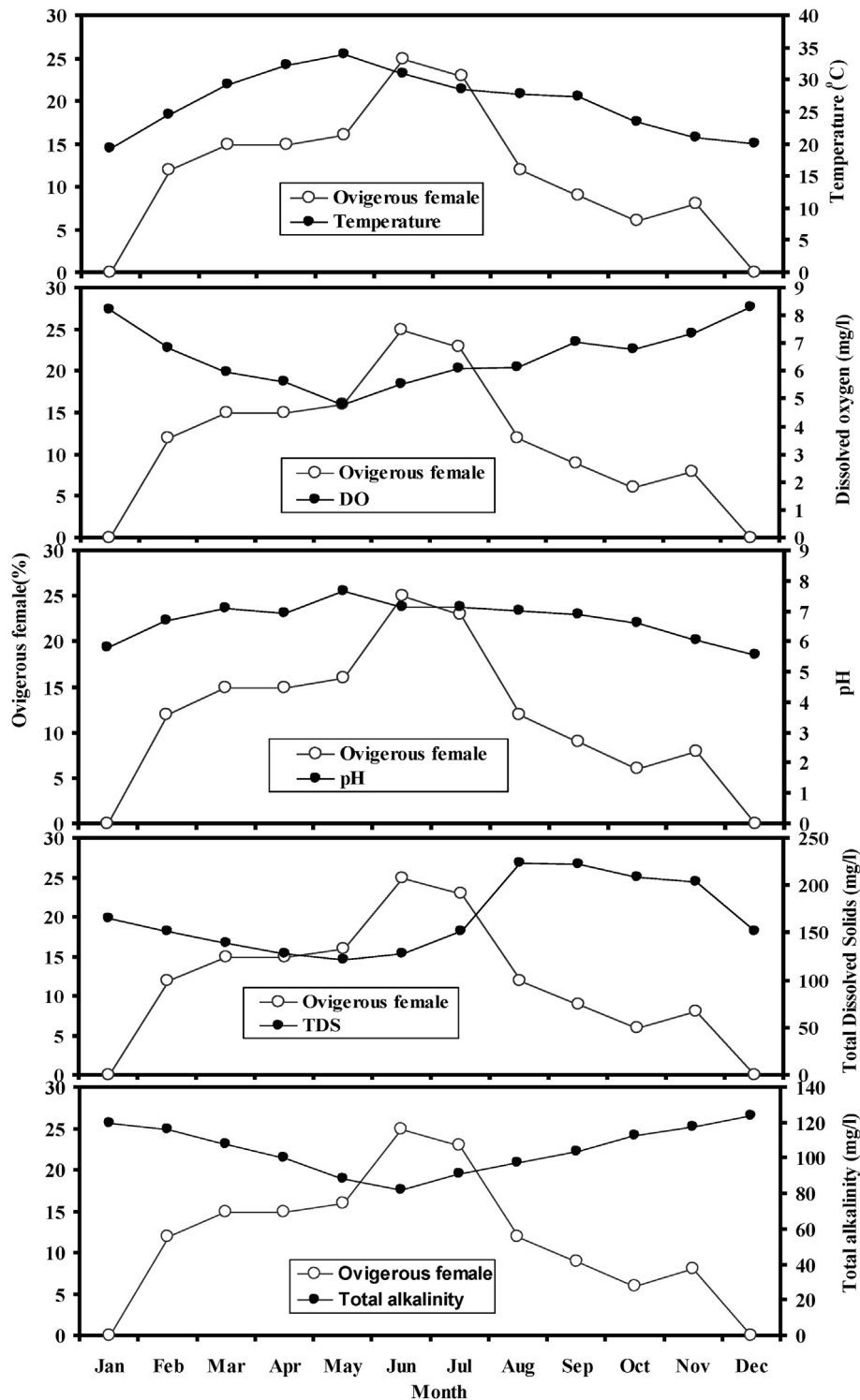


Fig. 7. Relationship between ovigerous females and environmental parameters of *Macrobrachium lamarrei* in the Ganges River, northwestern Bangladesh.

is increasing and rainfall is reducing day by day in the northwestern district of Bangladesh which alarmingly forecast the shifting of the spawning season of this species.

Spawning events are normally related to climatic conditions (Wilding et al., 2000). In the current study, we observed a highly significant relationship between rainfall vs. ovigerous females (%). The uppermost rainfall was noted in the month of June (389 mm) and this is the peak spawning season of *M. lamarrei*. The lowest rainfall was observed in November–January when the

ovigerous female (%) was also lowest. As it is the first work on this aspect, so comparison is not possible.

5. Conservation strategies

The L_m was 5.20 cm of *M. lamarrei* in the Ganges River that's mean 50% prawn spawn at this length so, smaller than this sizes are strongly prohibited to catch and bigger than this sizes are

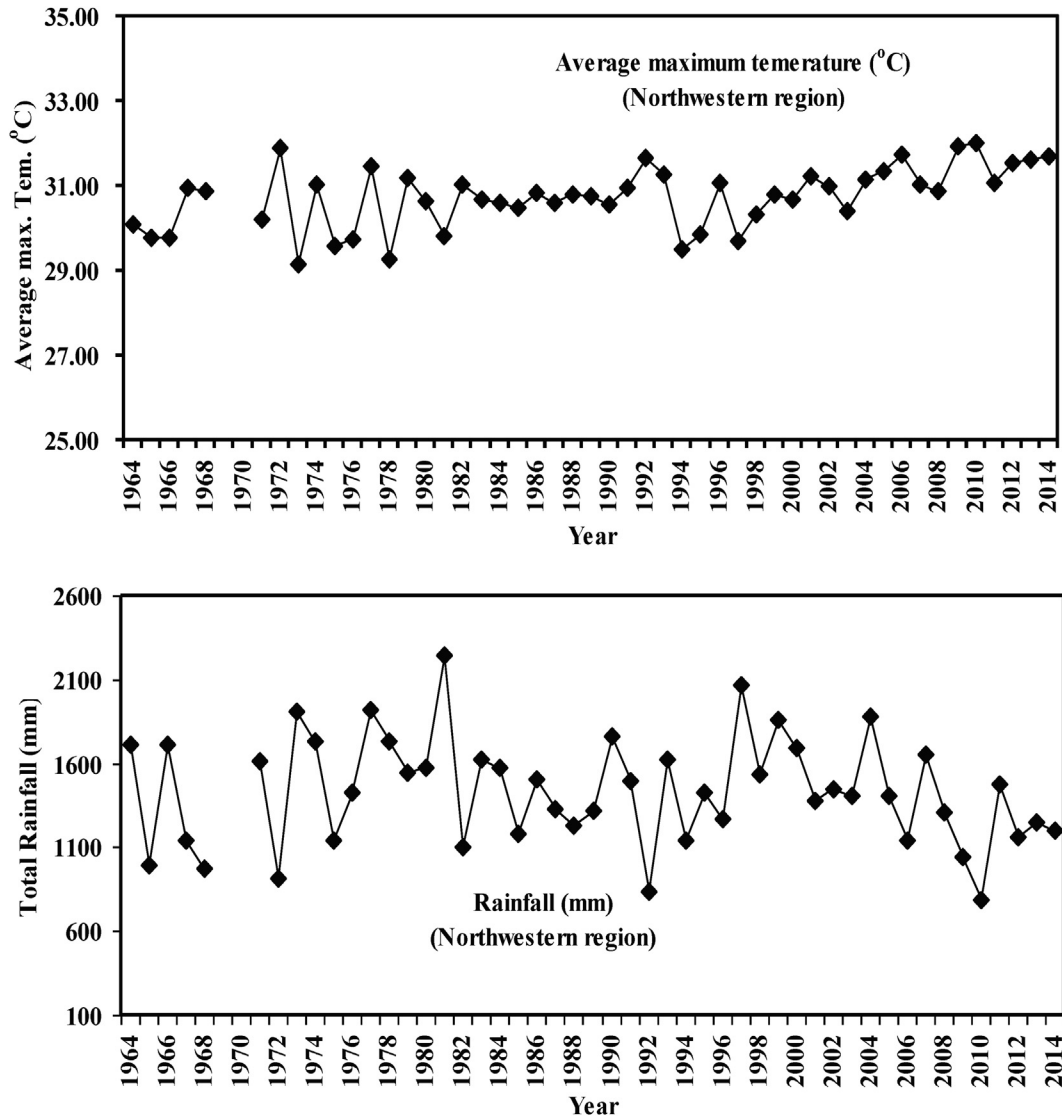


Fig. 8. Annual average maximum temperature (°C) and rainfall (mm) in the northwestern region, northwestern Bangladesh during 1964 to 2014.

recommended for exploitation. Catching of this species should be stop during their peak spawning season. The suitable range of K_F (0.85–1.03) should be maintained in hatchery for artificial breeding of this species. In addition, 80% of female may spawn at 32°C temperature so, this temperature could be maintained for artificial

breeding. Year by year temperature is rising and rainfall is decreasing that's why in future spawning may be shifted. So, short term management policies should be established for the management and conservation of the wild stock of *M. lamarrei*.

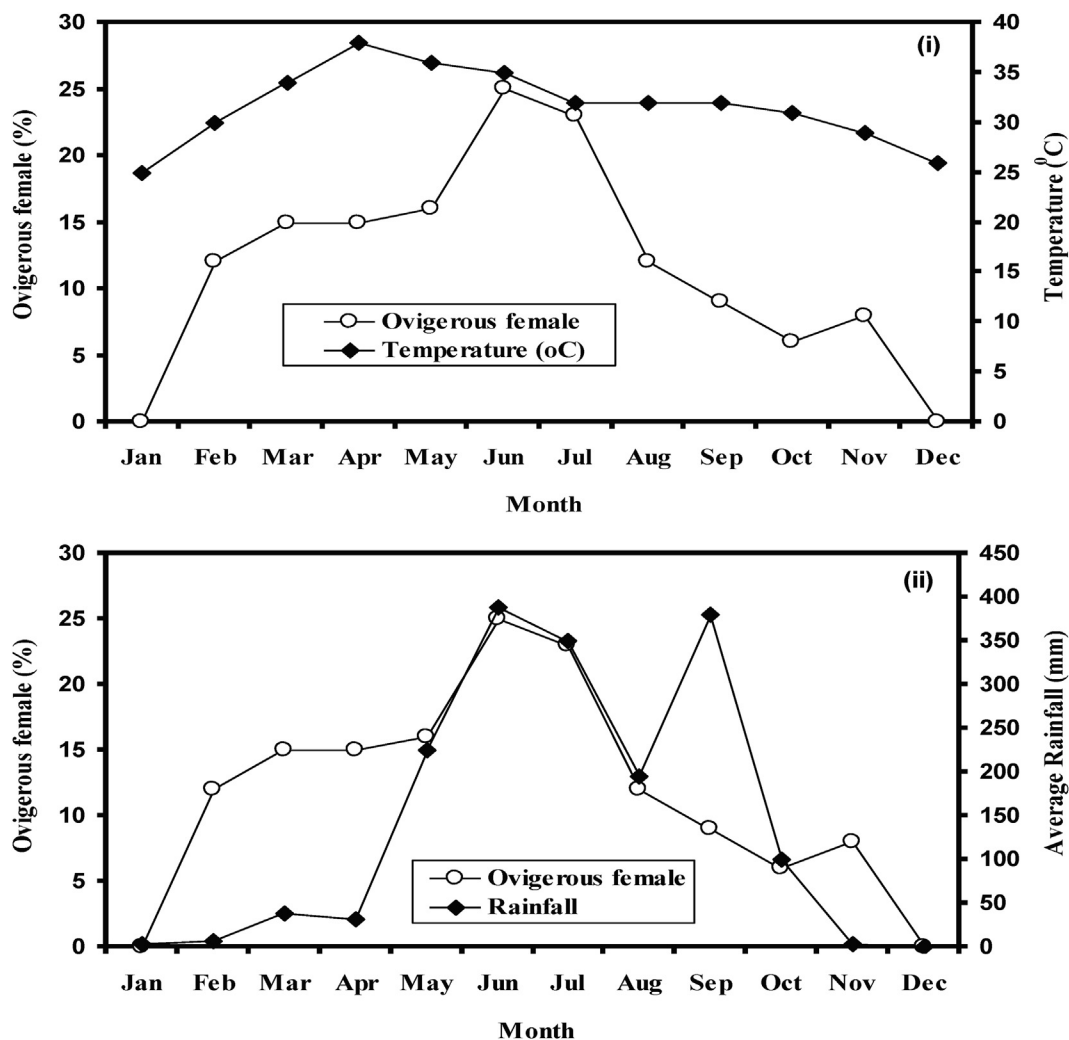


Fig. 9. Relationships between (i) temperature vs. ovigerous females and (ii) rainfall vs. ovigerous female of *Macrobrachium lamarrei* in the Ganges River.

6. Conclusion

Our research will be helpful to set the mesh size of nets based on L_m and establishment of ban period during peak spawning season is essential for the existence/conservation of *M. lamarrei* year after year in the Ganges River and worldwide water bodies. As well, a long series data of climate change showed the ups and down of temperature and rainfall which have significant impact on the reproduction of *M. lamarrei*. Therefore, it can be imagined that the spawning season might be shifted in the future which should be taken into consideration for successful management of *M. lamarrei* in the Ganges River as well as worldwide water bodies.

Declaration of Competing Interest

The author declare that there is no conflict of interest.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sjbs.2021.06.077>.

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