Dynamics of reproductive ecology of the fish *Ompok bimaculatus* (Siluriformes: Siluridae) in six tropical rivers of the Ganges basin, India

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ABSTRACT: The silurid butter catfish, *Ompok bimaculatus* (Bloch, 1794), is widely distributed in the plains and sub-mountain regions of India, but not enough is known about its reproductive potential is still insufficient. The present study evaluated the comparative reproductive potential (in terms of sex ratio, spawning season, body size at first gonadal maturity, gonadosomatic index, fecundity, egg dimension, egg weight etc.) of fish (n=1223) from six tropical tributaries of the Ganges basin during January 2011-December 2013. The females had relatively greater weight and length. The body size at 50% first gonadal maturity ($L_{50\%}$) ranged between 228-262mm in females and 198-247mm in males. The population has high and low fecundities. The correlations between absolute fecundity and total length, as well as between body weight and gonad weight, were significant (p<0.05) and positive in all the population.

Key words: Ganges basin, body size at first gonadal maturity, *Ompok bimaculatus,* reproductive potential, sex ratio, spawning season.

RESUMEN: Dinámica de la ecología reproductiva del pez *Ompok bimaculatus* (Siluriformes: Siluridae) en seis ríos tropicales de la cuenca del Ganges, India. El pez bagre de mantequilla, *Ompok bimaculatus* (Bloch, 1794), está ampliamente distribuído en las planicies y regiones submontañosas de la India, pero el conocimiento sobre su potencial reproductivo es deficiente. Este estudio evalua el potencial reproductivo comparativo (en términos de proporción de sexos, época de desove, tamaño del cuerpo a la primera madurez gonadal, índice gonadosomático, fecundidad, dimensión del huevo, peso de los huevos, etc.) de los peces muestreados (n=1223) de seis ríos tropicales de la cuenca del Ganges durante enero 2011 y diciembre 2013. Las hembras tenían peso y longitud relativamente mayor que los machos. El tamaño corporal al 50% de la primera madurez gonadal (L50%) osciló entre 228-262mm en las hembras y 198-247mm en los machos. La estrategia reproductiva tiene dos categorías, es decir, fecundidades altas y bajas. Las correlaciones entre la fecundidad absoluta y la longitud total, así como el peso corporal y el peso de las gónadas, fueron significativas (p <0,05) y positivas en toda la población.

Palabras clave: cuenca Ganges, tamaño del cuerpo a la primera madurez gonadal, *Ompok bimaculatus,* potencial reproductivo, proporción de sexos, época de desove.

The freshwater butter catfish *Ompok bimaculatus* (Bloch, 1794), locally known as 'Pabdha', is an indigenous catfish belonging to the family Siluridae and order Siluriformes. It is found in India, Pakistan, Bangladesh, Myanmar, Sri Lanka and Afghanistan (Talwar & Jhingaran, 1991). However, due to reduced abundance of fish in Indian waters, it has been listed as endangered (EN) by Lakra et al. (2010). The causes behind this could be due to several factors including habitat destruction and overfishing during the breeding season (Sarkar et al., 2013; 2014), wide use of pesticides in agriculture and gradual siltation in riverine habitat.

Information available on the reproductive biology of the tropical fish *O. bimaculatus* from Indian waters, particularly from Ganges basin is scanty. Therefore, a thorough knowledge on reproductive biology of the butter catfish is essential for better understanding on biology as well as for evaluating the commercial potentials, life history and cultural practices (Mollet et al., 2000). Information on size at maturity is crucial to captive propagation and spawning biology (Walker, 2004; Fontoura et al., 2009). The reproductive potential of a population is one of the basic exigencies to designate the individuals of the population in respect to their gonadal conditions (Jhingran & Verma, 1972). Although, some information is available on the distribution, abundance and captive breeding of *O. bimaculatus* (Rao & Karamchandani, 1986; Joshi et al., 2009; Atkore et al., 2011; Mishra et al., 2013), the information on reproductive potential of different wild population of this species and intra-specific variations in reproductive patterns is not available. The determination of spawning season and strategy of reproduction within the season and the life-cycle of the fish are prerequisites in assessing the reproductive potential of a population (Jhingran & Verma, 1972) and each population can develop phenotypic and genotypic differences over the time in these parameters due to reproductive isolation (Waldman et al., 1988). In view of the above, the present study was undertaken to understand the comparative pattern of reproductive potential using sex ratio, maturity stages, body size at first gonadal maturity, spawning season, gonado-somatic index, ova diameter and fecundity in six different populations of *O. bimaculatus* from the Ganges basin.

MATERIALS AND METHODS

Study area and sample collection: The present study is based on the sampling and collection of 1,223 mature specimens of *Ompok bimaculatus* (498 males and 725 females of similar size range), made during the period January, 2011 – December, 2013 from six different tributaries of the Ganges river basin (Fig. 1 and Table 1). Specimens were collected with gill, cast, drag and fry collecting nets. Specimens were also procured from nearby landing centers of the rivers, when not available during experimental fishing. For each individual, total length (TL, in mm) as well as standard length (SL, in mm) was measured to the nearest of 0.01 cm using digital slide calipers and total bodyweight (TW, g) was taken on a digital balance (ACCULAB, Sartoriusmodel no. VIC-412,) with 0.01 g accuracy. Whole gonads were removed from mature female specimens and weighed before being preserved in 10% formalin solution.

Sexual maturity and spawning periodicity: For studying maturity and determining spawning periodicity, different maturity stages of the female *O. bimaculatus* were classified based on colour, shape, size of the ovary, and the space it occupied in the body cavity. The details of the criterion used and the stages of maturity and spawning in both the sexes are presented in Table 2. The maturity stages of the ovary were determined as

TABLE 1
Sampling sites number of samples and GPS coordinates collected from six rivers of the Ganges basin during January 2011-December 2013. Nets used: gill, cast, drag and fry collecting nets

Rivers	Sampling sites	No. of samples	Gears used	GPS coordinates
Ganga	Kanpur	220	Cast, drag and fry collecting nets	N 26°30’28” E 80°19’01”
Gomti	Lucknow	399	Cast and drag	N 25°30’29” E 83°10’11”
Ramganga	Bareilly	188	Gill, fry collecting nets	N 26°28’21” E 80°19’52”
Ghaghara	Faizabad	173	Cast, drag and fry collecting nets	N 26°46’07” E 82°08’06”
Betwa	Jhansi	134	Gill, cast, drag net	N 25°26’55” E 78°34’11”
Sone	Rewa	109	Gill, drag net	N 28 º16.043’ E 08103.991”

TABLE 2
Criteria used for the determination of maturity stages of female *Ompokbimaculatus*

Maturity stage	Microscopic/ Macroscopic study of ovarian maturity
Immature (I)	Ovary small and slender; ova transparent with prominent nucleus, devoid of yolk; Testes thin and small.
Maturing (II)	Ovary enlarged ova granular, opaque and yellow in colour due to thick deposition of yolk deposition; ova clearly visible to naked eye; Testes yellowish, thin and extended nearly up to half of body cavity.
Mature (III)	Ovary greatly enlarged, occupying nearlythree quarterof body cavity; ova large, opaque, fully yolk laden and deep yellow in colour; Testes enlarged.
Fully Ripe (IV)	Ovary enlarged to occupy the entire length of the body cavity, large, mature and translucent ova, free from each other and glistening yellow in appearance; Testes enlarged covering about three quarterof body cavity.
Spent and resting (V)	Ovary shrunken and baggy, containing few large sized transparent ova in freshly spent fishes; Testes reduced.

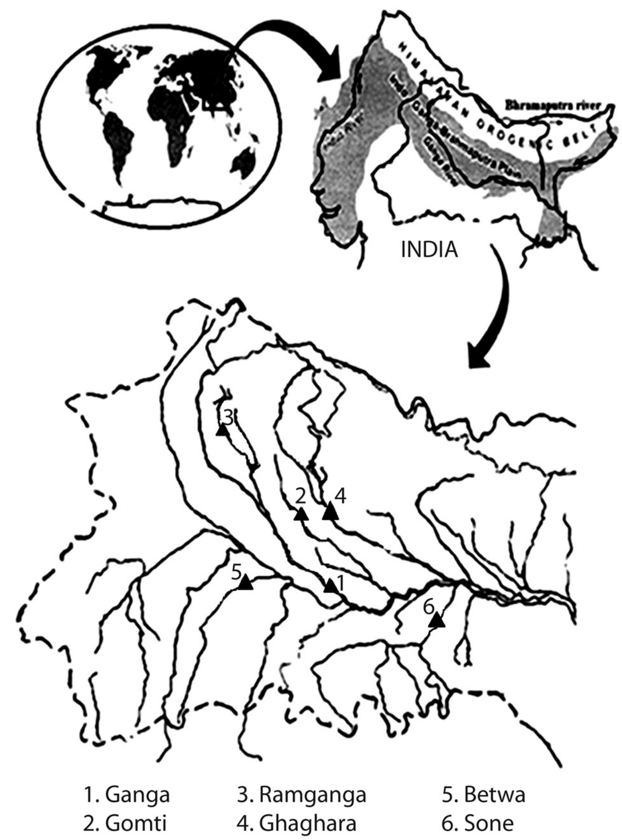

Fig. 1. Sampling sites and rivers of the Ganges basin.

per Rao and Karamchandani (1986), with minor modifications. The specimens were also sacrificed to check the gonadal development and different maturation stage of eggs during different months. Total weight and length of ovaries as well as testes were recorded. In addition, ova diameter and yolk deposition in the ova were also studied for recognizing the different maturity stages for female. The male specimens were sacrificed to dissect out the testes for examination.

Total body size at first gonadal maturity ($L_{50\%}$) and gonadosomatic index (GSI): The percentage of occurrence of various stages of maturity in different months was studied for 24 months. The spawning period was ascertained from occurrence of ripe specimens in the collected samples. Average size at first maturity ($L_{50\%}$) was defined as the size (the TL) at which 50% of individuals in the population reached sexual maturity during the reproductive period. The $L_{50\%}$ was determined by modeling the proportion of mature individual according to their length class for different populations. The $L_{50\%}$ was estimated using the logistic function expressed by the standard formula:

$$M = \frac{1}{1 + e^{[-A(L-L_{50})]}}$$

where M is the percentage of mature females by length class, L is the central value of the length class and A is the constant of the model. The suitable weight group was decided for plotting. The data collected for 24 months were pooled and the size at first maturity for both sexes was determined from the length measurements of the specimens and observation of maturity stages.

The gonadosomatic index was calculated on monthly basis using standard formula:

$$GSI = GWg * \frac{100}{Wb}$$

where GWg is gonad weight and Wb is total body weight.

Sex ratio: In this study, the data was pooled and the ratios of male to female were worked out month-, river- and length-wise to study the distribution of the sexes according to the season and size. To know homogeneity of the distribution of sex, Chi-square (c^2) test was applied (Snedecor & Cochran, 1967).

Fecundity and egg dimension: The gravimetric method was used for studying fecundity, which was based on the relationship between ovary weight and oocyte density in the ovary (Hunter & Goldberg 1980; Murua et al., 2003). Fecundity was estimated by counting the number of mature ova from a known weight of mature/ ripe ovary. Mature female ovaries were taken for estimation of the fecundity. The sub-samples were spread evenly on a counting slide with a few drops of water and the numbers of mature ova were counted and average number of three portions was used to determine fecundity using following formula:

$$F = \frac{Gonad\ weight}{Sample\ weight} * N$$

where F is the fecundity and N is the number of eggs in the sample.

To establish a relation of fecundity 'F' with total length 'TL' and total body weight 'TW',_and ovary weight 'OW' following formulas (Bagenal, 1978) were used: $F = aL^b$; $F = aW^b$ and $F = a\ OW^b$; where: a and b are constants, L= total length in mm, W = total bodyweight in g and OW = ovary weight in g. The least square method was used to determine the correlation coefficient between fecundity, TL and TW.

A small portion of the ovary was taken and the diameter of the intra-ovarian eggs was measured to the nearest of 0.01 mm using Nikon SMZ 1500 stereomicroscope. The maximum oocyte diameter was obtained by taking average measurements of at least 20 of the largest oocytes, which allowed in determining the minimum and maximum diameter of the oocyte as well as distribution of oocyte size. The mean weight of an oocyte was calculated by weighing 100 oocytes using a mini scales with 100^{th} g resolution. Only those oocytes were used which were belonging to the largest size mode in the gonads.

Statistical analysis: One-way analysis of variance (ANOVA) followed by multiple comparison Tukey test were performed on data of oocyte diameter with normal distribution and uniform variance to test differences between locations. When the data was not normally distributed and did not have uniform variance as for the fecundity and oocyte weight, a Kruskal–Wallis nonparametric ANOVA was performed to reveal significant differences in means between locations. The multiple linear regression method was applied to testify the correlation between environmental and reproductive parameters. Chi-square (c^2) test was used for sex ratio. A *p*-value of 0.05 was used as level of significance. These tests were performed using PAST 2.17c (Hammer, 2001) and ORIGIN software packages.

RESULTS

Spawning season: In immature fishes, the testis appears delicate with very small lobules. As maturity advances, they become thick and lobulated and appear milky white in colour and oozes milky milt on slight pressure. The ovaries in female were bi-lobed and asymmetrical; immature ovaries appeared creamy yellow in colour which became slightly brownish, distended and vascularized as they became ripe. The mature eggs were glistening yellow, glossy, heavily yolked and spherical. Maturity stages were divided in to immature, maturing, mature, fully ripe and spent. Different maturity stages of fish are summarized in Table 2.

Sex ratio: River-wise data on sex ratio of 1 223 individuals of *O. bimaculatus* were recorded. The females were relatively higher in total body weight and total length than males. In this comparative assessment of fish, more numbers of males were found in river Sone and females in river Ghaghara (Fig. 2). The pooled data from all rivers showed that the maximum male and female sex ratio and chi square value was recorded from river Gomti and minimum in river Sone (Table 3). The chi-square test indicated no significant (p>0.05) difference in the sex ratio among the populations studied.

Sexual maturity: The distribution of female mature samples (stage IV) during spawning season (June-July) from six different populations indicated different pattern in both the years (2011-2013) and uniform distribution of stage IV was observed, except river Gomti during 2013. Out of the six populations, four populations attained above 80% maturity, except river Ganga in which it was restricted within 40% in female. However, in case of river Gomti, the status of maturity of both male and

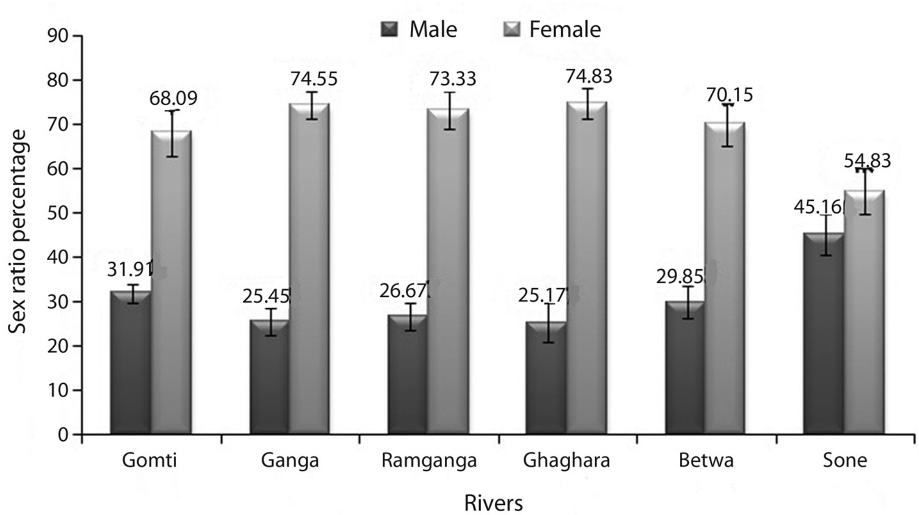

Fig. 2. Variation in sex ratio (%) of *Ompok bimaculatus* from six rivers of the Ganges basin.

TABLE 3
Comparative analysis of sex ratio of *Ompok bimaculatus*(male=498 and female=725)in the Ganges basin

Rivers	Mean TL (mm)±SD		Mean TW(g)±SD		M:F ratio	χ^2 value
	Male	Female	Male	Female		
Ganga	207.1 ± 27.3	213.8 ± 36.6	45.9 ± 22.2	60.0 ± 25.5	1:2.9	2.2
Gomti	201.0± 27.6	197.0 ± 30.8	53.6 ± 20.5	50.9 ± 23.2	1:1.6	17.3
Ramganga	245.6 ± 24.7	255.0± 26.5	84.7 ± 34.6	97.5 ± 49.4	1:2.2	1.7
Ghaghara	206.7± 32.1	188.8 ± 34.9	51.9 ± 24.1	43.5 ± 26.8	1:1.9	11.7
Betwa	242.7± 33.9	233.0 ± 33.5	69.2 ± 25.6	88.9 ± 33.7	1:1.9	17.2
Sone	252.3 ± 19.5	251.5 ± 26.8	88.5 ± 19.8	97.8 ± 29.1	1:1.1	1.1

TL: total length, TW: total bodyweight, SD: standard deviation.

female was surprisingly different in two different years. Although, the maturity of the female was ranged from 12.83- 83.0% (mean 52.70 ± 10.33) during 2012, but very less maturity (>10%, mean 3.22 ± 1.26) was recorded during 2013 indicating possibility of breeding and recruitment failure. Most of the males attained maturity during June-July (i.e. the breeding season of fish in the Ganges basin) in both the years from six undertaken populations, showed uniform pattern.

Body sizes at first gonadic maturity (L50%): The overall size at first gonadal maturity in males was smaller as compared to the females. In females, minimum $L_{50\%}$ was observed from the river Ghaghara and maximum from river Ramganga. In males, minimum $L_{50\%}$ was recorded from river Ghaghara and maximum from river Sone. Based on the results obtained from pooled analysis of six female populations, the reproductive strategy may be categorized into two types: two populations attained $L_{50\%}$ with mean TL ranged from 228 to 232 mm and four populations attained $L_{50\%}$ with mean TL range from 242 to 262 mm. In male, out of six populations, two populations attained $L_{50\%}$ with TL ranged from 198 to 216 mm, whereas four populations attained $L_{50\%}$ at 227-247 mm TL (Table 5).

Gonadosomatic index (GSI):The month and river-wise distribution of GSI of *O. bimaculatus* is depicted in Figure 3. In our study, the female GSI of six population showed uniform pattern with higher value during June-August, whereas in case of male higher value was showed in four population during (June - August), while in two population this was recorded during May (Fig. 3). It is evident from the results that the GSI values increased slowly from January to March and then sharply increased in June corresponding with the spawning period. Out of the six populations, maximum GSI in males was recorded from river Sone followed by Gomti, Ghaghara, Ganga, Ramganga and Betwa, respectively. The analysis of variance (ANOVA) indicated non-significant difference in mean GSI of male and female among 6 population ($p<0.08$ in male, $p< 0.55$ in female).

Fecundity: About 104 mature female ovaries were taken for estimation of the fecundity. About 100 mg of sub-sample was taken from three segments (anterior, middle and posterior) of each ovary with accuracy of 0.05g. In the present study, the mean absolute fecundity of fish ranged from 4,260 to 18,382 for the individuals having TL from 189.9 to 267.5 mm (Table 4 and Fig. 4). Two distinct types of reproductive patterns can be demonstrated from the six river populations: i.e. (*i*) high fecundity and (*ii*) low fecundity. Higher absolute fecundity was recorded in 5 rivers, whereas the lower absolute fecundity was recorded only in the main channel of river Ganga. Specimens sampled from river Betwa had significantly higher absolute fecundity than the other five river populations.

Correlation between fecundity, total length, total bodyweight and ovary weight: Table 4 showed the relationships between fecundity and total TL as well as between total TW and OW of the species. There was significant ($p<0.05$) and positive correlation between absolute fecundity and TL, TW and OW in all the populations. The correlation between fecundity and TL was significantly ($p<0.05$) stronger in river Ghaghara followed by Sone, Ramganga, Gomti, Betwa and Ganga, whereas the correlation between fecundity and TW was significantly stronger in rivers Ramganga followed by Betwa, Ganga, Gomti, Ghaghara and Sone. Rivers Ghaghara, Gomti and Sone showed significantly stronger correlations between

TABLE 4
Relationship between mean absolute fecundity, TL: total length, TW: total body weight and OW: ovary weight in female *Ompok bimaculatus* in different rivers of the Gangesbasin

Rivers	No. of samples	Mean TL (range) (mm)	Mean TW (range) (g)	Mean OW (range) (g)	Mean (range)	TL vs Fecundity			TW vs Fecundity			OW vs Fecundity		
						a	*b*	r^2	*a* ± SE	*b* ± SE	r^2	*a* ± SE	*b* ± SE	r^2
Ganga	18	212.7 (170-250)	49.1 (14.5-102.1)	3.2 (1.9-5.3)	4260.0±2314.8^b (2475.7-7873.6)	-2.5±0.15	2.5±0.1	0.96	2.5±0.1	0.9±0.0	0.97	4.2±0.1	0.5±0.1	0.97
Gomti	25	248.6 (225-265)	109.9 (68.1-135.1)	11.2 (1.5-20.2)	18382.8±9230.6^b (1406.3-34680.3)	-4±0.17	3.2±0.2	0.97	2.4±0.1	0.9±0.1	0.97	3.2±0.2	0.9±0.1	0.98
Ramganga	22	266.3 (240-320)	146.6 (101.8-272)	14.5 (8.4-18.3)	13378.7±14101.1^b (2882.7-35677.7)	-2.3±0.12	3.5±0.2	0.98	2.3±0.1	0.9±0.0	0.99	3.8±0.1	0.7±0.0	0.97
Ghaghara	27	189.9 (140-252)	54.6 (18.6-22.6)	6.5 (1.1-15.6)	11328.6±10679.2^a (1417.8-30050.5)	-2.4±0.14	3±0.1	0.99	2.3±0.1	0.9±0.0	0.97	3.4±0.1	0.8±0.0	0.98
Betwa	23	259.1 (242-275)	119.3 (98.2-156.5)	13.8 (4.5-25.9)	18173.9±14399.6^b (5343.9-46743.1)	-2.9±0.17	2.5±0.1	0.97	2.3±0.1	0.9±0.0	0.97	3.9±0.1	0.6±0.0	0.97
Sone	20	267.5 (245-290)	113.9 (92.0-150)	4.7 (1.6-11.7)	11465.3±9932.9^b (1669.2-27398)	-2.6±0.15	3.6±0.2	0.98	2.2±0.1	0.9±0.0	0.97	3.4±0.1	0.8±0.1	0.98

Superscript *a* indicates for no significant difference (p>0.05); *b* for significant difference (p<0.05)"SE: standard error".

fecundity and OW followed by rivers Ganga, Betwa, Ramganga (Figs. 5-7). Overall, it was found that the exponential value for TL–fecundity was more than that of TW–fecundity. Value for OW–fecundity was slightly lower than that of TW–fecundity.

Condition factor: The average condition factor (K) for two years was significantly (p<0.05) different during the spawning season among the rivers (Table 5). The highest K was recorded in *O. bimaculatus* collected from rivers Gomti, Betwa and Ghaghara. Fish caught in rivers Ganga, Ramganga and Sone had the lowest K.

Egg dimension: In ripe and gravid females, the yolked egg became rapidly differentiated and comprised around 98% of the total ova. The oocyte distribution during the fish breeding season (June -August) was almost uniform within the ovary and the ova size was observed to be maximum in size during June-July. There was no significant difference in average oocyte diameters (Table 5).

DISCUSSION

In the present study, the predominant occurrence of mature and ripe stages of female ovaries of *O. bimaculatus* from six different rivers during April to August indicated that *O. bimaculatus* has a prolonged spawning season, with individuals showing river wise variation in spawning months with a peak in June. These results also corroborate with other previous studies for *O. bimaculatus* in other river as reported by Mishra et al. (2013). Khumar and Siddiqui (1991) reported overall marginal dominance of males over females. The variation in sex ratio might be due to effects of different factors such as differential mortality, growth rate, longevity, sex reversal, seasons, fishing grounds and fishing methods (Pathak & Jhingran, 1977; Deepak, 2005). This deviation may also be due to patterns of migration or behavioral differences or the partial segregation of mature forms through habitat preference between males and females (Collignon, 1960; Polonsky & Tormosova, 1969; Reynolds, 1974).

The size at sexual maturity was also varied in males and females *O. bimaculatus* across different rivers of the Ganges basin. It was observed that male specimens attained maturity earlier than female individuals which may be attributed to the faster growth of male than females due to favorable ecological conditions and food availability (Gupta et al., 2014). The reason for this varied pattern might be due to the large varieties of food items in the reservoir which is an advantage for gonadal material

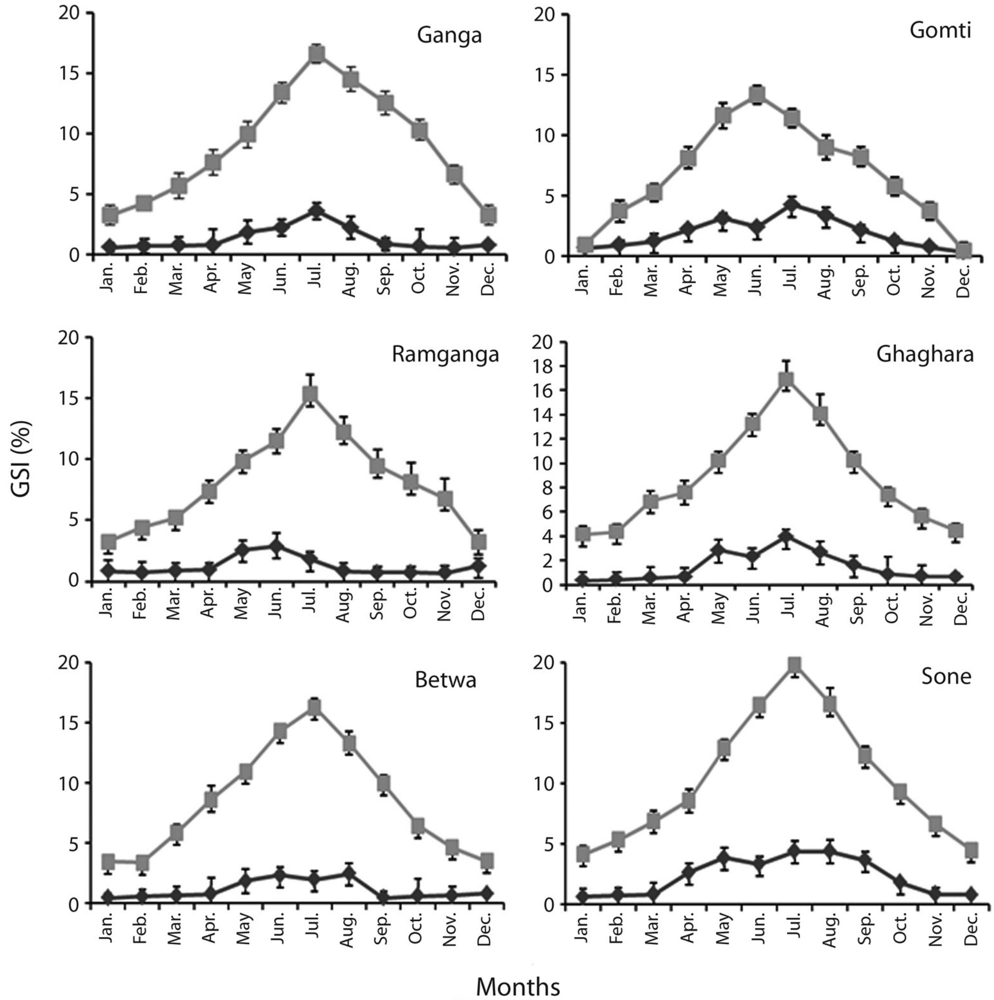

Fig. 3. Monthly changes in gonadosomatic index (GSI) for *Ompok bimaculatus* in six rivers of the Ganges basin. Circles and Squares indicate males and females, respectively. Vertical lines show standard deviation (SD).

TABLE 5
Mean ± SDof condition factor and reproductive parameters of *Ompok bimaculatus* from six populations from different rivers of the Ganges basin

Rivers	Condition factor	Oocyte diameter (mm)	Size at first maturity ($L_{50\%}$)	
			Female	Male
Ganga	0.57±0.14[a]	0.5±0.1[a]	247	216
Gomti	0.63±0.24[a]	0.6±0.1[a]	232	227
Ramganga	0.55±0.15[b]	0.6±0.1[a]	262	242
Ghaghara	0.60±0.0.17[a]	0.8±0.0[a]	228	198
Betwa	0.62±0.11[b]	0.5±0.1[a]	242	238
Sone	0.57±0.07[a]	0.6±0.1[a]	249	247

Superscript *a* indicates for no significant difference (p>0.05); *b* for significant difference (p<0.05)SD: Standard deviation.

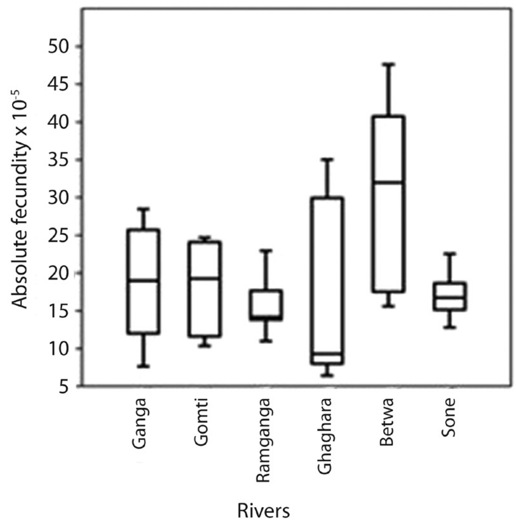

Fig. 4. Absolute fecundity of *Ompok bimaculatus* from six rivers of the Ganges basin.

production to meet the egg or milt production round the year. It was observed that female fish attained maturity earlier than male in all the river population which is similar in other *Ompok* species (Mishra et al., 2013; Gupta et al., 2014). The considerable variation in $L_{50\%}$ among the different river populations can be attributed to several environmental factors, food supply and parasitism (Le Cren, 1951) and hormonal functions (Kume et al., 2009) which have great influence on the health of the fish.

In this study, percentage of gonadal maturity (stage IV) of fish in rivers Ganga (during 2012 and 2013) and Gomti (during 2013) was considerably less, which might be due to hydrological changes, overexploitation, habitat destruction and some unknown factors (Singh et al., 2010; Gupta et al., 2010). In our study, breeding activity of O. *bimaculatus* in the rivers was coterminous with the rainy season. Thus, rainfall and linked factor, like temperature, may act as a sign for spawning by the fish so that

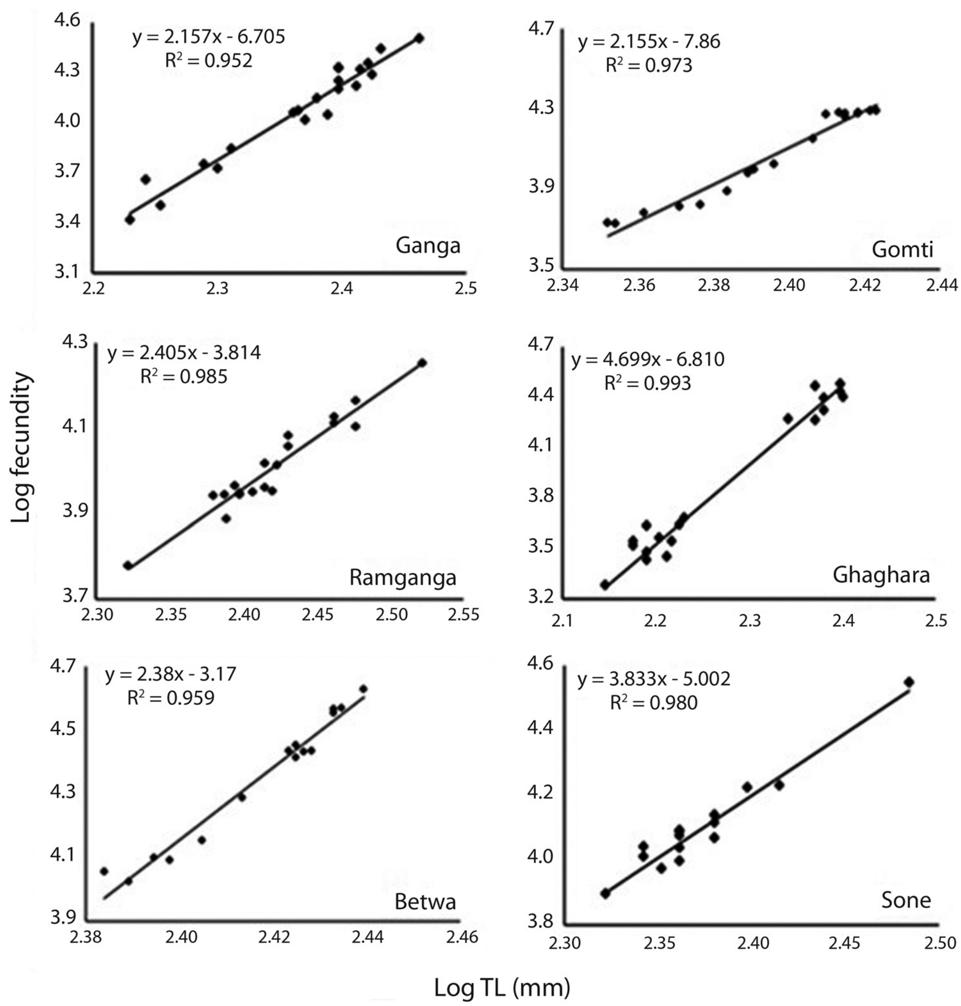

Fig. 5. Linear regression between total length and fecundity of *Ompok bimaculatus.*

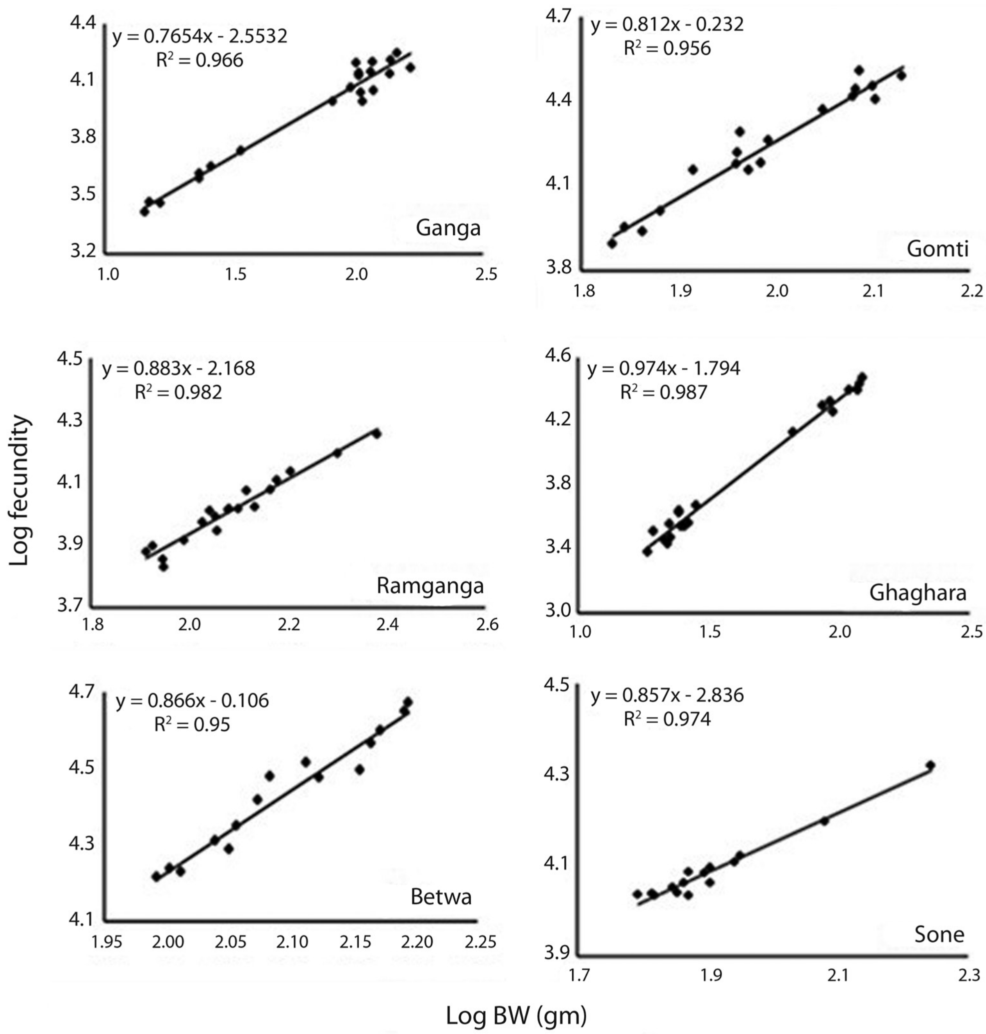

Fig. 6. Linear regression between body weight and fecundity of *Ompok bimaculatus.*

the offspring is produced as a time of better growth and survival. A correlation between rainfall and peak breeding activity has also been reported for other species (Admassu 1994, 1996, Teferi, 1997). In the recent years, the growing pollution in these two rivers made a noticeable change in its physical habitat and physicochemical characteristic that might be the probable cause of biological changes in fishes (Sarkar et al., 2012a). Several studies have reported the disruption in gonadal development, variation in maturity stages, malformation of the germ cells and/or reproductive ducts to altered gamete production of fishes in the rivers that received large volumes of sewage and industrial effluents (Jobling, 2002; Perera-Garcia et al., 2011).

Overall, in our study, higher absolute fecundity was recorded in all the 5 rivers, except river Ganga. The fecundity of this fish was low in comparison with the other *Ompok* species, for example the fecundity of *O. pabda* was about 30 000 (Gupta et al., 2014). This shows that the population of *O. bimaculatus* in the river is under stress. Variation in the fecundity of fish from six different rivers recorded in this study may depend on different factors such as protein and genetic variation, size, age, condition of the fish and food intake by the fish. Consequently, the dependency of fecundity on food supply is quite clear. Similar studies also evidences that this kind of variation in the number of eggs produced by an individual female is generally dependent on the factors like size, age, environmental conditions, food availability, vitamin and type of species (Dube, 1993; Bagenal, 1957; Bhuiyan et al., 2006). Among other different factors, like nutritional status, time of sampling and maturation stages have also

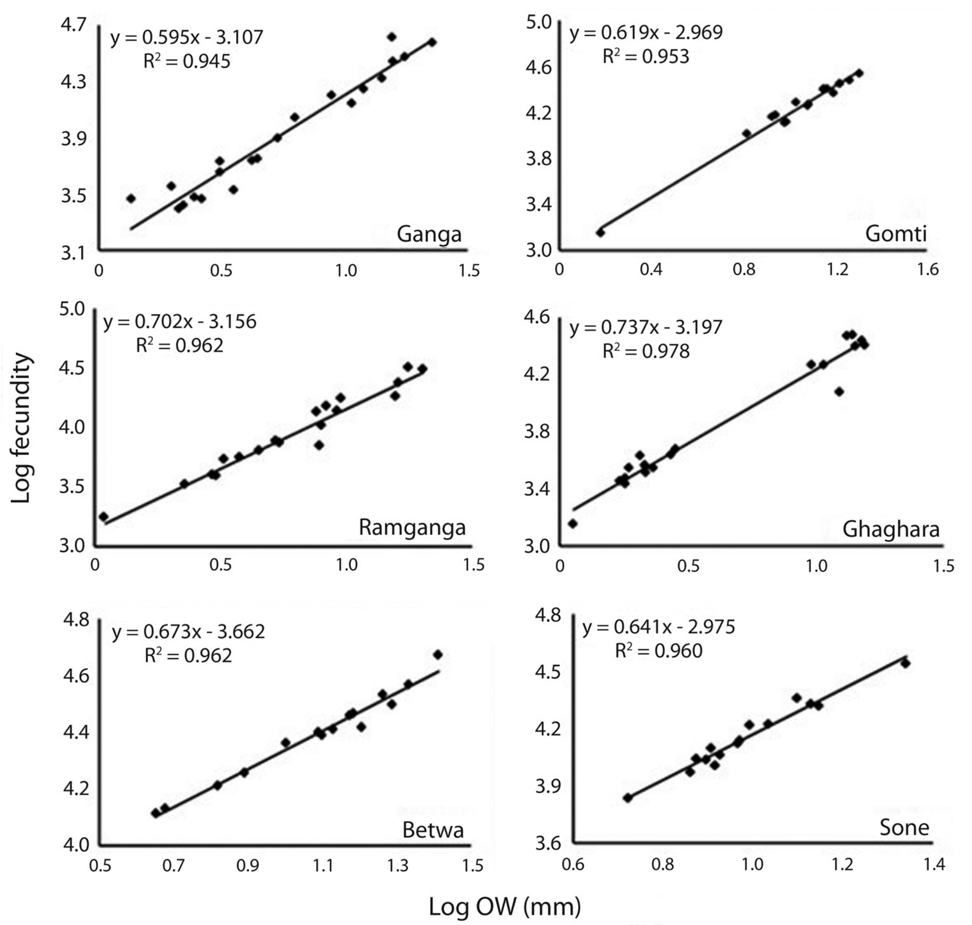

Fig. 7. Linear regression between ovary weight and fecundity of *Ompok bimaculatus.*

been reported to affect the fecundity both within the species and among the fish populations (Sarkar et al., 2012b). The relationship of fecundity, which increased with the increase in the body parameters, TL, TW and OW of *O. bimaculatus,* showed positive correlation (r^2= 0.95 to 0.99) in six populations studied. In previous studies, linear relationships between fecundity and weight were reported (Rao, 1981; Musa & Bhuiyan, 2007; Sarkar et al., 2009; Mir et al., 2013). Studies of Bindu et al. (2012); Buragohain and Goswami (2014) and Gupta et al. (2014) also reported significant relationships between length and body weight of fish as well as between ovary weight and fecundity in other catfish species (*Horabagrus brachysoma*, *Clarias magur* and *O. pabda*). The differences in condition factors among different rivers may also be attributed to low feeding intensity and degeneration of ovaries during winter and high feeding intensity and full development of ovaries at the maturity periods (Chatterjee et al., 1977; Sarkar et al., 1999; Fontoura, 2009).

The review of literature showed intra-specific differences among populations in life history traits, including age at first reproduction, fecundity etc., which can be related to thermal effects like winter mortality (Teriokhin & Budilova, 2008; Hautekeete et al., 2009) or to food availability (Jonsson & Sandlund, 1979; Walther et al., 2010). There also exists considerable evidence to suggest that population variation in life history traits reflect adaptation by fish to local environment (Taylor, 1991; Conover & Schultx, 1997). Moreover, some individuals within a population may mature earlier or at smaller size than others, often as a result of the existence of alternative reproductive strategies or in response to predation pressure. The latitudinal differences may also affect the life history traits in freshwater fishes (Gotelli & Pyron, 1991; Heibo et al., 2005; Munch & Salinas, 2009). Geuye et al. (2012) reported significant variation in reproductive traits (*i.e.* fecundity, oocyte diameter, oocyte weight, condition factor, GSI) of the fishes of coastal, marine, freshwater and estuarine ecosystems. In the Ganges basin, some workers have reported significant regional variation in several reproductive traits of fish (Sarkar et al., 2008, 2009; Mir et al., 2013); however, very less data is available on these complex processes.

In this study, the mean egg dimension of *O. bimaculatus* was comparatively higher in rivers Gomti, Betwa and Sone. The variation within different populations might be due to variation in water turbulence and proximity and population density of spawner (Denny & Shibata, 1989; Levitan & Petersen, 1995). Further, average increase in egg size and egg number might decrease as environmental quality declines and environmental variability increases (Smith & Fretwell, 1974; Einum & Fleming, 2004). Similar variations were also reported in captive reared population of another catfish *O. pabda* (Chakrabarti et al., 2009; Ezenwa et al., 1986). These variations were also probably due to differences in individual ovulation time and the stage of egg development (Ezenwa, 1981).

In conclusion, the present observations indicated that the wild populations of butter catfish *O. bimaculatus* showed considerable variation in the reproductive attributes. Hence, appropriate strategies need to be framed accordingly for its sustainable management and conservation in different drainages and tributaries of the Ganges basin.

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