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RESEARCH PAPER

Dynamics of Inter-Population Reproductive Pattern in Butter Catfish, *Ompok Bimaculatus* (Bloch, 1794) from Different Rivers in India

Uttam Kumar Sarkar[1, *], Praveen Agnihotri[2], Ravindra Kumar[2], Abhishek Awasthi[2], Brijesh Kumar Pandey[2], Abha Mishra[3]

[1] ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata - 700120, India.
[2] National Bureau of Fish Genetic Resources, Canal Ring Road, Post - Dilkusha, Lucknow -226 002, (U.P.), India.
[3] Dr Babasaheb Bhimrao Ambedker University, Lucknow.
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* Corresponding Author: Tel.: +91.522 2442440; Fax: +91.522 2442403;
E-mail: usarkar1@rediffmail.com

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Abstract

This study demonstrates the comparative pattern of reproductive parameters viz. sex ratio, size at first gonadal maturity, gonadosomatic index (GSI), fecundity, egg dimension of *O. bimaculatus* analyzed from 13 different rivers during 2011–2013. It was observed that females start to mature earlier than males and mean size at first maturity in male and female varied considerably between the different populations. The reproductive period of fish were extended from April - August while in Southern rivers it was extended from March to July. The results indicated three types of reproductive patterns of *O. bimaculatus* in terms of age at first sexual maturity and absolute fecundity and distinct variation was observed across different rivers. The meanabsolute fecundity varied significantly between the rivers and was grouped in to three categories: (i) high absolute fecundity (ii) medium fecundity and (iii) low fecundity. The results indicated significant and positive correlation between absolute fecundity and total length, body weight and ovary weight in all the rivers ($P<0.05$). The oocyte distribution during the maturity season was consistent within the ovary but more fluctuations were observed within different population. This study provides quantitative account in to the comparative reproductive potential and inter-population reproductive strategies for the first time.

Keywords: *Ompok bimaculatus*; comparative assessment; reproductive traits; wild population.

Introduction

In recent years, unsustainable capture of wild population and habitat degradation of riverine ecosystem is an emerging conservation issue in the tropics, which has resulted in the population decline of several species. One such commercially important food fish and potential species for freshwater aquaculture, is currently considered to be under threatened category is Silurid butter catfish *Ompok bimaculatus* (Bloch, 1794). It is found in India, Pakistan, Bangladesh, Myanmar, Sri Lanka and Afghanistan (Pethiyagoda, 1991; Rahman, 1989; Talwar and Jhingran, 1991). They are widely distributed in the plains and sub mountain regions and found in streams, rivers, reservoirs and tanks (Parameswaran *et al.*, 1967). The fish has a wide geographical distribution covering West Bengal, Bihar and North-Eastern States of India as well butover the last few decades its wild population is declining rapidly (> 50%). Due to its good aquaculture potential as well as high conservation value and commercial demand it has been declared as a State Fish (Lakra and Sarkar, 2011).

A comprehensive understanding of the life history traits is of great significance in conservation biology. Artificial breeding and captive propagation of species is linked to its critical life history parameters such as growth, fecundity, reproductive potential, size at first maturity, oocyte size and oocyte weight, distribution of maturity stages etc. Studies on the reproductive biology of any fish are essential in evaluating the commercial potentialities of its stock, life history, cultural practice and actual management of fishes (Mollet *et al.*, 2000). For instance, information on size at maturity is crucial to fishery management (Fontoura *et al.*, 2009; Walker *et al.*, 2004). The reproductive potential of a population is one of the basic exigencies to designate the individuals of that population in respect to their gonadal conditions (Jhingran and Verma, 1972).

The analyses of different life history traits have been widely used by ichthyologists to differentiate among different species and different populations within a species (Ihssen *et al.*, 1981) and continue to be used successfully (Froese, 2006). Studies of morphological variation among populations continue to have an important role to play in stock

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identification, despite the advent of biochemical and molecular genetic techniques which accumulate neutral genetic differences among groups. Studies on the reproduction and maturity of fish provides baseline information that typically assists with the initial recognition and delineation of geographic regions that are representative of individual stocks (Pawson and Jennings, 1996) and is an almost essential prerequisite for successful stock identification (Griffiths, 1997). The use of such parameters is an efficient and cost-effective mean for stock identification, as these data are routinely collected for assessment and management purposes (Ihssen *et al.,* 1981). Although the utility of these parameters for stock identification appears to decrease with stock complexity, their applicability increases with the number and diversity of parameters examined (Begg and Waldman, 1999). To date, information concerning the reproductive potential of butter catfish is very limited and despite its economic importance, no systematic studies have been done. Previous studies have established length weight relationship (Sivakami, 1987), condition factor (Parameshwaran *et al.*, 1970; Qayyum and Qasim, 1965), spawning biology (Raizada *et al.*, 2013; Rao and Karamchandani, 1986; Sridhar *et al.*, 1998) and genetic characterization (Malakar *et al.*, 2013). The life history of *O. bimaculatus* has earlier been described by many researchers (Chakrabarty *et al.*, 2007; Choudhuri, 1962; Mukherjee and Das, 2002; Rao, 1981; Sarkar *et al.*, 2005); however, no attempts have been made on comparative analysis of reproductive traits of fish from different wild population. Therefore, the present study was attempted to better understand the comparative pattern of reproductive biology of thirteen different populations of *O. bimaculatus* distributed to wide geographical ranges and comprehensive quantification of results which may be helpful for regional management of this important species in India and other adjoining countries.

Materials and Methods

Sample Collection and Design

Samples were collected during 2011-2013 from thirteen major rivers in India and the details of the collected rivers along with geographical coordinates are presented in Table 1. Fish samples were collected with the help of local fishermen using drag net, cast net and locally available traps. The fishes were anesthetized with MS-222 (Ethyl 3-amino benzoate methane sulfonate), in case of live sampling, before dissection.

For each individual, total length (TL), standard length (SL) and fork length (FL) was measured on a digital balance with 0.01 cm using digital slide calipers, and whole body weight (BW) was taken on digital balance 0.01g accuracy. Fish gonads were extracted, weighed and preserved in 70% ethanol. Gonads were separated and subsequently weighed to 0.5 g macroscopically analyzed for sex determination and detection of maturity stages. We considered six commonly identified stages: stage I- immature, stage II- maturing process, stage III- mature, stage IV- fully ripe and V- spent and resting and the descriptions of the different stages have been shown in Table 2. These were determined according to colour, relative size of gonads and oocyte diameter in case of females and presence of milt in case of males.

Size at First Gonadal Maturity and Sex Ratio

The average size at which 50% of the fish matured ($L_{50\%}$) was determined. The mean 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 spawning season. The $L_{50\%}$was determined by modeling the proportion of mature individuals according to their length class for different populations using statistical software Origin (v9.4) (Originlab, 2016) and was estimated using the

Table 1. Details of sampling sites, number of samples and GPS coordinates collected from 13 different rivers in India

Sl. No.	Rivers	Samples (N)	GPS Coordinates of sampling sites
1.	Ganga	69	N 24°48' E 87°55'
2.	Hooghly	98	N 30°22' E 78°28'
3.	Sharda	166	N 28º16' E 81º03'
4.	Chambal	32	N 26°29′E 77°15′
5.	Subarnarekha	52	N 21°33′E 87°23′
6.	Brahmaputra	32	N 26º10'E 91º41'
7.	Narmada	132	N 22º45'E 77º43' and N 23º6' E 79º55'
8.	Godavari	73	N 18º58' E 72º49'
9.	Krishna	44	N 19°22′ E 73°17′
10.	Cauveri	27	N 12°24′ E76°34′
11.	Tapti	92	N 21º14'E 73º35'
12.	Amaravati	16	N 10°52' E 77°58'
13.	Mahanadi	42	N 19°53′ E 85°35′

Table 2. Criteria used for the determination of maturity stages of *O. bimaculatus* (modified after Rao and Karamchandani, 1986)

Sl. No.	Maturity stage	Microscopic/ Macroscopic study of ovarian maturity
1.	Immature (I)	Ovary small and slender; ova transparent with prominent nucleus, devoid of yolk; testes thin and small.
2.	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 ½ of body cavity.
3.	Mature (III)	Ovary greatly enlarged, occupying nearly ¾ of body cavity; ova large, opaque, fully yolk laden and deep yellow in colour; testes enlarged.
4.	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; maximum ova diameter 0.58 mm, testes enlarged covering about ¾ of body cavity.
5.	Spent and resting (V)	Ovary shrunken and baggy, containing few large sized transparent ova in freshly spent fishes, testes reduced.

standard formula:

$$M=1/1+e\ [-A\ (L-L_{50}].$$

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.

Differences in sex ratio during reproduction period were determined. The number of males and females were recorded for two years and data was pooled and the ratio of males to females was worked length wise to study the distribution of sexes. To know homogeneity of the distribution of sex Chi-square test was applied (Snedcor and Cochran, 1980) and the formula used was: $\chi2 = (O - E)^2/E$, where, "O" is observed frequencies and "E" is expected frequencies. The gravimetric method was used for studying fecundity, which is based on the relation between ovary weight and oocyte density in the ovary (Hunter and Goldberg, 1980; Murua *et al.*, 2003).

Gonadosomatic Index and Total Fecundity

The GSI was calculated using the standard formula:

GSI =Wg * 100/Wb; where: Wg = Gonad weight and, Wb = Total body weight.

Preserved ovaries were used to estimate total fecundity and oocyte size frequency distribution. Total fecundity was estimated only using mature females (stage IV). Only ovaries with mature yolked and unovulated eggs were used to avoid underestimating fecundity due to early spawning or eggs lost during handling (Heins and Baker, 1993). For the estimation of fecundity, three subsamples of ovary ware taken from the front, mid and rear sections of each ovary and weighed. The total number of eggs in each ovary subsample was then proportionally estimated using the equation, F_1= (gonad weight X number of eggs in the subsample)/sub-sample weight. All oocytes in the subsamples were counted manually. Regression analysis of the L_T, W_T and ovary weight on fecundity and egg weight, gonadosomatic index on fecundity were carried out. To establish a relation of fecundity "F" with total length "TL" and body weight "TW" the following formula (Bagenal and Tesch, 1978) was used: $F = aL^b$, where, *a* & *b* are constants. "L" is total length in mm and "W" is total weight in g. The least square method was used to determine the correlation coefficient between fecundity and total length and body weight.

Condition Factor

The condition factor was calculated using the standard formula:

$$K = W*100/L3:$$

where W = weight of fish in gm. L = Total length of fish in cm.

Egg Size and Weight

A small portion of the ovary was taken and the diameter of the intraovarian eggs were measured to the nearest 0.01 mm using Nikon SMZ 1500 binocular microscope loaded with NIS Elements D 4.00.00 software with image analysis devices. The maximum oocyte diameter for mature females was obtained by averaging the measurements of at least 20 of the largest oocytes. It also allows determining the minimum and maximum diameter of the oocyte in the sample as well as the oocyte size distribution. The mean weight of an oocyte was determined by weighing 100 oocytes using a mini scale with hundredth gram resolution. Only those oocytes were belonging to the largest size mode in the gonads were used.

Statistical Analysis

The statistical analyses were carried out using one way ANOVA followed by multiple comparison

Tukey test in order to see the differences between the locations. A Kruskal–Wallis nonparametric test was performed to reveal significant differences in means between locations. Relationships between fecundity and total length (TL), bodyweight (BW) and ovary weight (OW) were identified using Pearson's correlation (2-tailed) and further quantified using linear regressionusing SPSS v12.0.

Results

Sexual Dimorphism and Sex Ratio

In the present study, the reproductive period of *O. bimaculatus* in most of the rivers of Ganges basin extended from April - August and in Southern rivers it was extended from March to July. Sexual dimorphism was apparent only during the spawning season. It was distinguishable from the month of March-April, May-June in Brahmaputra and June-July in other rivers and tributaries of the Ganges basin. In case of female, the pectoral fin was smooth and genital papilla was found swollen and reddish in color. The abdomen was soft and bulging in appearance. The size of the female is generally thicker, broader and bigger comparing to the male. In males, pectoral fins become rough and serrated edge, the genital papilla pointed and narrow with freely oozing milt, while applying slight pressure on the abdomen. The paired mature ovaries of *O. bimaculatus* are unequal in size and length of right ovary is more than left ovary in all the populations. The overall sex ratio of male: female in the exploited catches indicated the dominance of females, except river Brahmaputra (Table 3). The Chi-square test indicated no significant difference (P>0.05) in the sex ratio between the populations studied.

Size at First Gonadal Maturity ($L_{50\%}$)

The minimum size at which fish attains gonadal maturity was determined based on the examination of the maturity stages. Based on the results obtained from pooled analysis of 13 female populations, 10 populations showed $L_{50\%}$ with mean TL ranging 200-250 mm, one population attained $L_{50\%}$ at the range of 263 mm, whereas in rest two, (Ganges and Mahanadi) the $L_{50\%}$ was recorded as 199 and 197 mm TL. In male, out of 13 populations, 10 populations attained $L_{50\%}$ with TL ranged from 200 - 250 mm, whereas one population (Cauvery) attained $L_{50\%}$ at 256 mm TL. Two populations (Sharda and Ganga) showed $L_{50\%}$ below 200 mm. Among the studied population, the female $L_{50\%}$ was higher at Cauvery and lower at river Mahanadi. Overall, the results indicated considerable variations in length at first gonadal maturity of both female and male across 13 different rivers.

Distribution of Sexual Maturity Stages

The distribution of maturity stages of *O. bimaculatus* in 13 different rivers during different months showed that in most of the population mature females (stage IV) were recorded in June-July. The 100% of maturity of female was recorded during July 2012 and after that the maturity was recorded during March 2013. The 60% maturity of male recorded

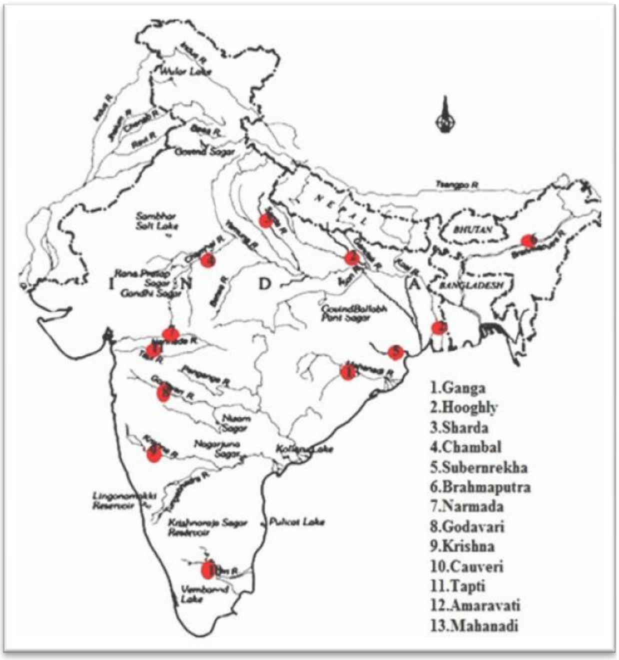

Figure 1. Map of the rivers studied (area of study)
(P.S. River Amaravati merged into single identification mark on the map under its parent River Cauveri keeping in view the proximity of sampling sites).

during July 2012 and after that the 80% maturity (stage IV) was recorded in during March 2013. It was also observed that most of the matured samples (<70%) were recorded in June-July from11 rivers, except rivers Narmada and Sharda.

Gonado Somatic Index (GSI)

A total of 884 samples of *O. bimaculatus* were obtained and the GSI recorded increased towards the spawning period for both sexes. All male and female captured between June to August were fully matured. The river-wise patterns of average GSI of both male and female *O. bimaculatus* indicated considerable variation during different seasons and fluctuate between 0.99 to 13.20 in female and 0.37 to 10.20 in male. Overall, the average GSI of female was higher during June-August in most of the rivers. During the

Table 3. Comparative analysis of sex ratio of *O. bimaculatus* in 13 different rivers

River(s)	Length Male (mm)	Length Female (mm)	%Male in sample	%Female in sample	Sex ratio (M:F)	Chi Square value (χ2)
Ganga	100-230	120-280	25.45	74.55	1:2.93	13.25
Hooghly	158-280	155-410	40	60.00	1:1.5	5.80
Sharda	130-260	135-280	31.90	68.10	1:2.13	15.21
Chambal	220-292	125-310	37.50	62.50	1:1.66	2.00
Subarnarekha	150-320	140-310	43.48	56.52	1:1.30	0.78
Brahmaputra	200-270	175-280	56.67	43.33	1:0.76	0.53
Narmada	140-250	145-260	49.28	50.72	1:1.02	0.01
Godavari	195-260	130-333	37.50	62.50	1:1.67	4.00
Krishna	230-290	210-305	27.27	72.73	1:2.67	9.09
Cauveri	230-350	190-340	33.33	66.67	1:20	3.33
Amaravati	215-230	185-232	31.25	68.75	1:2.2	2.25
Tapti	140-280	135-330	38.71	61.29	1:1.58	3.16
Mahanadi	140-275	140-265	40	60.00	1:1.50	1.60

Table 4. Mean ± (SD) of condition factor and reproductive parameters of *Ompok bimaculatus* from 13 wild populations. Superscript '*a*' indicate significant difference (P<0.05). The size at first maturity of male and female populations was significantly different (P<0.05)

Rivers	Condition factor	Absolute fecundity	Oocyte diameter (mm)
Ganga	0.26±0.01[a]	4163.7±1414.0[a]	0.51±0.05
Hooghly	0.53±0.10	14396.9±5388.6	0.47±0.07
Sharda	0.55±0.92[a]	6813.2±4110.8[a]	0.49±0.04
Chambal	0.98±0.05	21995.0±12115.0	0.53±0.19
Subarnarekha	1.47±0.07	23549.9±17386.4[a]	0.56±0.18
Brahmaputra	0.48±0.04	12490.0±4085.9	0.50±0.22
Narmada	0.85±0.05[a]	23226.8±5184.5[a]	0.39±0.22
Godavari	0.61±0.12	11518.8±9222.7	0.28±0.06[a]
Krishna	0.74±0.08	15306.3±6837.1	0.58±0.26
Cauveri	1.54±0.31	23050.1±20142.2	0.57±0.24
Tapti	0.61±0.12	13099.6±6183.9	0.54±0.22
Amaravati	0.53±0.08	11492.9±2985.8	0.44±0..24
Mahanadi	0.42±0.16	5293.2±4677.0	0.44±0.24

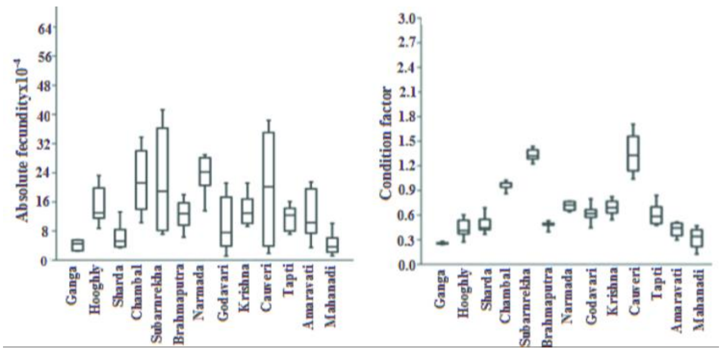

Figure 2. Absolute fecundity and condition factor of *O. bimaculatus* from 13 rivers.

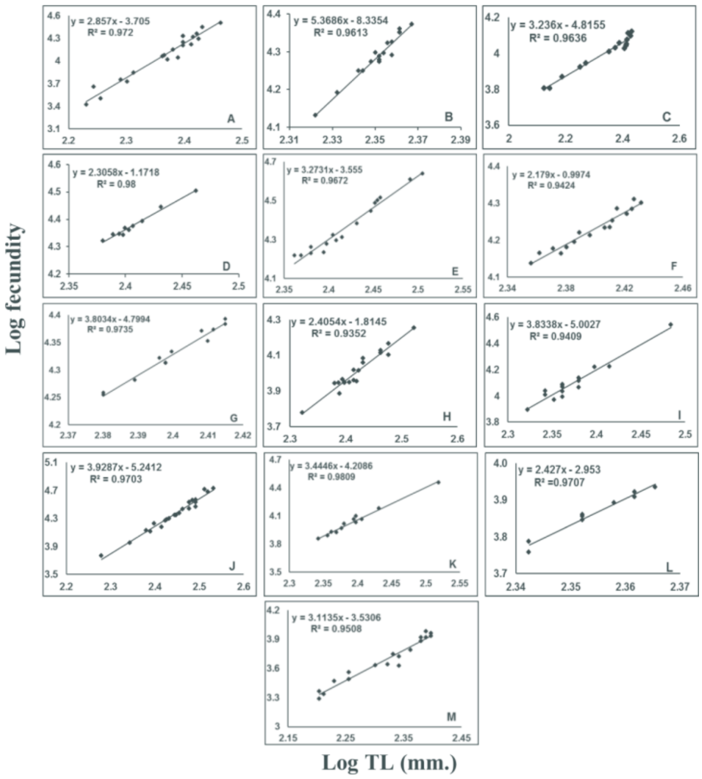

Figure 3. Linear regression between total length and fecundity of *O. bimaculatus* from 13 rivers. (A) Ganga, (B) Hooghly, (C) Sharda, (D) Chambal, (E) Subarnrekha, (F) Brahmaputra, (G) Narmada, (H) Godavari, (I) Krishna, (J) Cauveri, (K) Tapti, (L) Amaravati, (M) Mahanadi.

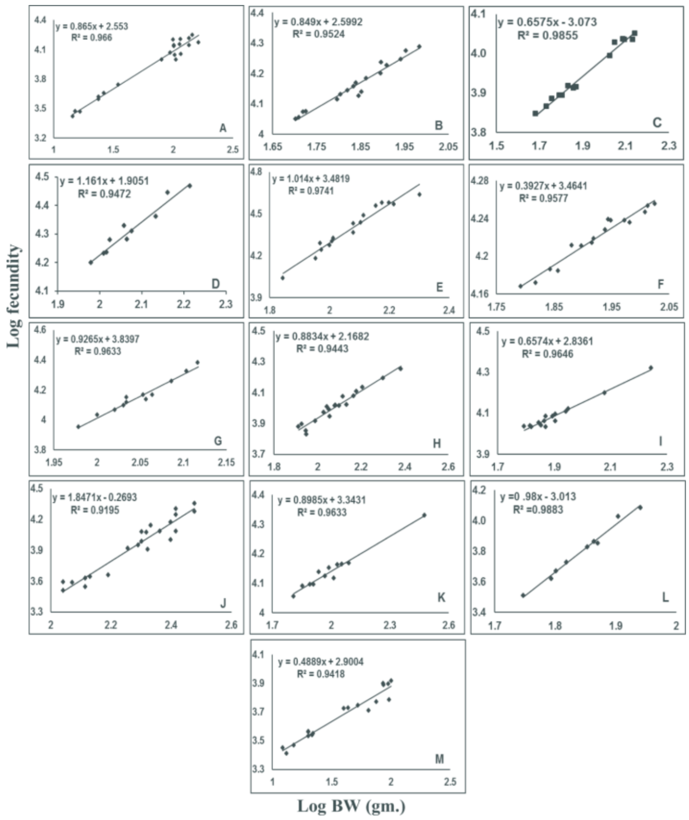

Figure 4. Linear regression between body weight and fecundity of *O. bimaculatus* from 13 rivers. (A) Ganga, (B) Hooghly, (C) Sharda, (D) Chambal, (E) Subarnrekha, (F) Brahmaputra, (G) Narmada, (H) Godavari, (I) Krishna, (J) Cauveri, (K) Tapti, (L) Amaravati, (M) Mahanadi.

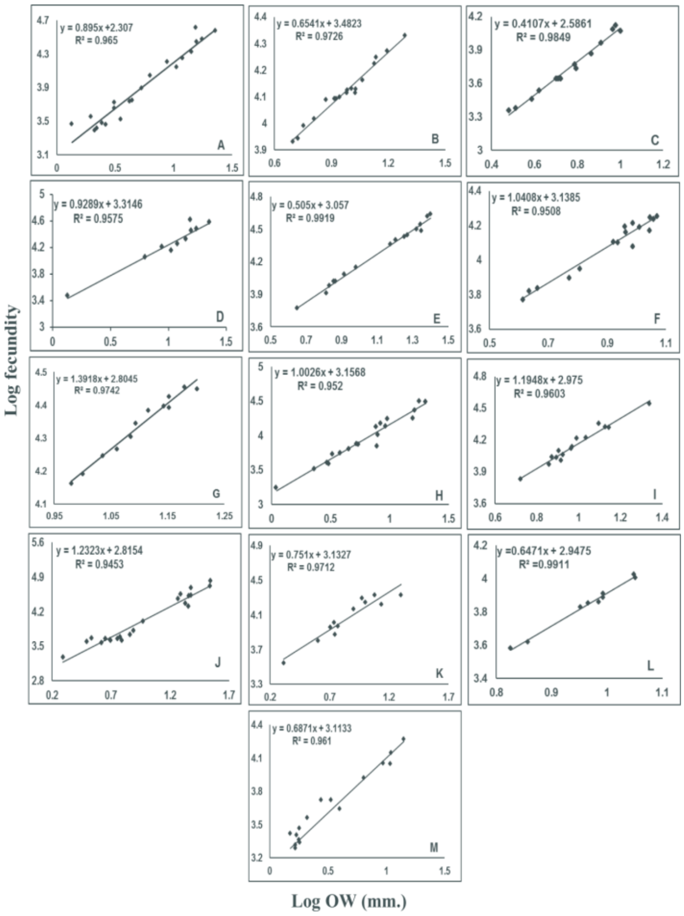

Figure 5. Linear regression between ovary weight and fecundity of *O. bimaculatus.* (A) Ganga, (B) Hooghly, (C) Sharda, (D) Chambal, (E) subarnrekha, (F) Brahmaputra, (G) Narmada, (H) Godavari, (I) Krishna, (J) Cauveri, (K) Tapti, (L) Amaravati, (M) Mahanadi.

spawning season, the mean GSI of female of 13 populations was ranged from 0.99±0.77 to 13.20±1.85. For males, GSI was ranged from 0.37±0.05 to 1.78±0.03 during June and in July it was much varied from 0.37±0.05 to 10.20±1.47, respectively.

Fecundity

The matured yolked oocytes of *O. bimaculatus* are distributed randomly in the ovary; thus, facilitating fecundity studies from any part without bias. The absolute fecundity showed significant variation (Kruskal Wallis test; P<0.05) within the different wild population as shown in Table 4 and Figure 2. In the present study 245female fishes were observed for determination of fecundity and it was found that the individual fecundity of fish varied from 4163.68 to 23,549.9 as shown in Table 4. Three types of reproductive patterns of fish can be notable from this study: (*i*) high absolute fecundity (*ii*) moderate absolute fecundity (*iii*) low absolute fecundity in 13 river populations. Higher absolute fecundity was recorded in 4 rivers out while moderate absolute fecundity was recorded in 6 rivers and lower absolute fecundity was observed in 3 rivers (Table 4, Figure. 2).

Correlations between Fecundity and Totallength (TL), Bodyweight (BW) and Ovary Weight (OW)

Figures 3, 4 and 5 represent the relationship between fecundity and the TL, BW and OW of fish. The results indicated significant and positive correlation between absolute fecundity and TL, BW and OW in all 13 the rivers (P<0.05). The correlation was much stronger between ovary weight and fecundity followed by BW and fecundity and TL and fecundity.

Fish Condition Factor (K)

The average condition factor considering two years combined was significantly different (P<0.05) between the rivers (Figure. 2, Table 4) and ranged from 0.26±0.01 to 1.54±0.92 during the spawning period. The best condition factor was recorded in female *O. bimaculatus* collected from rivers, Subarnarekha, Narmada and Krishna (Figure. 3). Fish caught in river Ganga, Mahanadi, Brahmaputra had

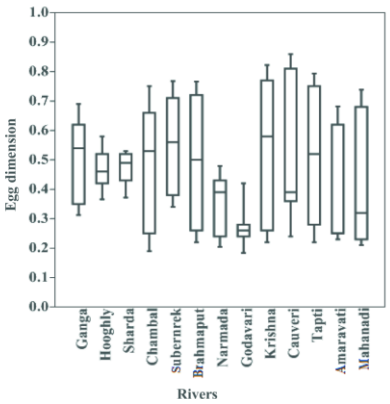

Figure 6. Comparative analysis of oocyte dimension (mm) of *O. bimaculatus* from 13 different populations.

the lowest conditions.

Oocyte Size and Weight

In ripe and gravid female, the yolked eggs became rapidly differentiated and comprised around 98% of the total ova. The oocyte distribution during the maturity season was consistent within the ovary but more fluctuations were observed within different population.The ova size was observed to be maximum in sizein river Krishna and minimum in river Godavari as shown in Table 4 and Figure 6. There was considerable difference in average oocyte diameter. The egg-weight was also calculated to estimate the reproductive output of different populations and considerable variation was observed among different population. The average oocyte weight exhibited showed minimum 0.28 ± 0.06 mg in river Godavari while maximum of 0.58 ± 0.11 mg was recorded in river Krishna. Larger and more nutrient-rich eggs will usually yield larger and healthier offspring with higher chances of survival in the wild.

Discussion

The results of the present study demonstrate the pattern of riverwisevariation in reproductive traits of *O. bimaculatus*. Reproduction is a necessary parameter in the application of population dynamics to assess the state of the exploited resources and facilitate their management (Sley *et al.,* 2012). The information on reproductive traits and morphometric relationships of *O. bimaculatus* from different wild population is not available except some fragmentary literature (Banik *et al.,* 2011; Mishra *et al.,* 2013; Raizada *et al.,* 2013; Rao and Karamchandani, 1986; Sridhar *et al.,* 1998). The present study is the first attempt to determine the intraspecific variation of the reproductive traits from 13 geographically isolated populations. This study shows that reproductive traits and morphometric relationship of the 13 population differed considerably in many attributes. The differences in reproductive potential of *O. bimaculatus* among different populations may reflect environmentally induced phenotypic plasticity and /or genetic variations (Gueye *et al.,* 2012). In a recent study, Malakar *et al.* (2013) reported relatively high genetic diversity of *O. bimaculatus* using cyt-b gene of three different riverine populations of *O. bimaculatus*. It can be predicted, therefore, that the *O bimaculatus* populations studied here and showing high variations in reproductive traits are genetically distinct. However, further studies are required to compliment such hypothesis.

The sex ratio observed is skewed in favour of female in each population, characteristic for a variety of fish species. Sex ratio of fish may deviate from the normal 1:1 due to number of factors (Alp *et al.,* 2003; Nikolsky, 1963). The sex ratio obtained for *O. bimaculatus* indicated a predominance of females, which is also the case of other freshwater cat fish species. The differences in sex ratio of the different population may be related to reproduction or to sexual differences in growth, habitat occupancy, or mortality and selectivity caused by type and size of fishing gears. The length data on *O. bimaculatus* shows that females were predominant in the larger size classes which might be due to the ability of female to achieve greater lengths in a given age group.

The size at first maturity of *O. bimaculatus* has not been reported earlier from all the 13 rivers studied. The average size of first sexual maturity of female and male were different considerably. In this study female *O. bimaculatus* in River Mahanadi reached maturity at a smaller size than fish from other rivers, with mature females ranging from 197 to 263 mm. These differences may be the result of differential fishery exploitation and the result of different selectivity of gears used, because at high level of exploitation, larger and older individuals are harvested. The differences in reproductive traits among populations may reflect environmentally induced phenotypic plasticity and/or genetic variations. In another study (Sivakami, 1982) the minimum size (230 mm) was reported as the length at first maturity of fish. However, our results on maturity and spawning season are in conformity with the studies reported (Raizada *et al.*, 2013; Sridhar *et al.,* 1998).

In the present study, higher absolute fecundity was recorded in 4 rivers, moderate absolute fecundity was recorded in 6 rivers and lower absolute fecundity ranged from 3 rivers (Table 4). Overall, the absolute fecundity was lower in rivers Ganga, Sharda and Mahanadi as compared others. These findings are partially justified by the poorer condition factors recorded in the above rivers. The other factors for low fecundity might be overexploitation, habitat degradation and unsustainable harvesting. However, specific reason is not clear. The fecundity was better correlated with total length followed by body weight and gonad weight. Likewise, spawn weight (i.e. total weight of eggs), indicative of reproductive effort, was higher in rivers Cauvery, Subarnarekha, and Chambal samples. Variation in the fecundity of fish from different rivers may depend on different factors such as size of the fish, age and condition and space and food intake by the fish. A large part of the variation in absolute fecundity among the different populations resulted from interpopulation variation in body length and weight. Studies reported that in different populations, some other factors like nutritional status (Gupta *et al.*, 2014; Sarkar *et al.*, 2009) and time of sampling, maturation stage have also so far been reported to affect the fecundity both within the species and between fish populations. Therefore, variation in fecundities across different rivers of the Ganges basin during the present study was not an exception. There are reports that salinity, temperature and dissolved oxygen are among the abiotic factors which are likely to impact the fecundity and egg size (De Silva, 1986; Legendre and Ecoutin, 1989). High linear relationship and positive correlation (r^2= 0.94 to 0.98) was observed between absolute fecundity and TL, BW and OW in all the populations studied. Similarly, linear relationships between fecundity and weight have been reported by other authors (Arthi *et al.*, 2013; Mir *et al.*, 2013; Rao, 1981; Sarkar *et al.*, 2009). In addition to the above, several other studies (Bindu *et al.*, 2012; Buragohain and Goswami, 2014; Gupta *et al.*, 2014) have reported significant relationship between fish length, body weight and ovary weight and fecundity in other catfish viz. *Horabagrus brachysoma*, *Clarias magur* and *Ompok pabda*. Additionally, higher absolute fecundity in Black-chined Tilapia was also correlated with the good condition factor as reported by Gueye *et al.* (2012).

In this study we have not yet determined genetic variation of *O. bimaculatus*, but previous studies have revealed genetic differentiation levels suggesting very limited gene flow among populations (Malakar *et al.*, 2013). Biological effects and/ or unsustainable fishing practices may lead to a modification of their reproductive strategies: decreasing their L_{50} and increasing their reproduction effort (Kovacic, 2004; Perera-Garcia *et al.*, 2011). However, environmental pressures may also play an important role in the changes in these life history characteristics, including temperature, water quality, onset time and duration of monsoon and flooding cycles (Gueye *et al*., 2012; Sarkar *et al.*, 2010). Among others, differences in food resources in the rivers sites/ or efficiency at foraging and prey availability can also influence reproductive parameters and fish condition (Gueye *et al*., 2012).

Several studies reported intraspecific differences between populations in different traits, viz. age at first reproduction, which can be related to thermal effects like winter mortality (Hautekeete *et al.*, 2009) or to food availability (Walther *et al.*, 2010). Additionally, within a population, some individuals 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 (Kwarfo-Apegyah and Ofori-Danson, 2010). There exists considerable evidence to suggest that population variation in life history traits reflects adaptation by fishes to local environment (Conover and Schultz, 1997; Taylor, 1991). There are also reports on latitudinal differences in life history traits in freshwater fishes (Gotelli and Pyron, 1991; Heibo *et al.*, 2005; Sarkar *et al.*, 2009). Significant variation in reproductive traits (fecundity, oocyte diameter, oocyte weight, condition factor, GSI) of black chinned tilapia females from various coastal marine, freshwater and estuarine ecosystems was reported (Gueye *et al*., 2012).

In the present study the egg dimension of *O. bimaculatus* was comparatively higher in rivers Cauvery, Chambal, Tapti and Sharda. Variations in egg diameter of fish have been reported in captive reared population (Chakrabarty *et al.*, 2007; Ezenwa *et al.*, 1986). The variations are probably due to differences in individual ovulation time and the stage of egg development (Ezenwa, 1981). Such variation also might be due to the sufficient availability of food and environmental factors at this stage of life. This study also indicates significant positive relationship between the absolute fecundity, total length (TL), total body weight (BW) and ovary weight (OW) in different riverine populationof *O. bimaculatus.*

Conclusion

In conclusion these studies provide a comprehensive quantitative account of the reproductive pattern of butter catfish *O. bimaculatus* of 13 important rivers in India and contribute current knowledge of fish. The baseline data may facilitate the development of stock assessment models and could be utilized for regional management of the fish species. Future research should address on the spatio-temporal pattern and molecular characterization of the species to ensure adequate evaluation through their natural distribution. The study also provides new insight in to the inter-population reproductive strategies and may be helpful for stock identification as well as responsible management of wild population.

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