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Biology of reproduction in *Otolithoides pama* (Hamilton, 1822) in Hooghly-Matlah Estuary of West Bengal, India

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ABSTRACT

Pama croaker *Otolithoides pama* (Hamilton, 1822) is one of the commercially important demersal fish of Hooghly-Matlah estuarine system, West Bengal, India. Reproductive biology of 618 samples of *O. pama* (Hamilton, 1822) collected from the Hooghly-Matlah estuarine system of West Bengal, India for a period of 18 months (November 2016 to April 2018) was investigated. The total length (TL), body weight (BW) and ovary weight (OW) of the samples varied from 100-384 mm, 7.29-470.71 g and 1.5-29.49 g, respectively. The sex distribution was 1 male for 1.07 female and the ratio did not differ statistically. The length at first maturity (L_m) was recorded as 183 mm for males and 196 mm for females. The reproductive activity was found throughout the year with three peak spawning season with high gonadosomatic index (GSI) values, *i.e.*, during February-March, June and September-November. The absolute fecundity ranged from 4652 to 170688 eggs (24950±32441.2) and relative fecundity ranged from 96 to 808 eggs per g body weight (382±176.8). Fecundity exhibited a relatively higher significant correlation with ovary weight ($r = 0.973$, $p<0.01$), compared to total length, total weight and ovary length. Egg diameter frequency showed polymodal distribution, indicating that the species is a batch or asynchronous spawner.

Keywords: Estuarine croaker, Fecundity, Maturity stages, Ova diameter, Reproductive biology

Introduction

Estuaries are one of the most productive habitats of the world, which give suitable environment for the growth and survival of marine as well as freshwater migrants (Barbosa *et al.,* 2012; Bhakta *et al.,* 2018). The Hooghly-Matlah estuarine system on the east coast of India is the largest and most productive estuaries in the country (Jhingran and Ghosh, 1978; Bhakta *et al*., 2019a), covering a distance of about 295 km from the sea face and accounting for 8029 km^2 area. It is a positive estuary in the mixo-haline range, where salinity ranges from 0.1 to more than 30‰ (Pantulu, 1966).

The estimated total annual fish catch from Hooghly-Matlah estuarine system fluctuated from 62165.4 to 117,639 t for the period between 1998-99 and 2010-11 with an annual average catch of 66027.0 t showing a sharp increase of catch (Nath *et al.,* 2004; Ayyappan *et al.*, 2011). Sciaenids constituted an important commercial fishery in the state of West Bengal with an annual average catch of 20,861 t (11.45% of state marine catch) from 2015-16 (Anon., 2016) and *Otolithoides pama* contributed maximum share. *O. pama* locally called 'Bhola' forms an important fishery in Hooghly-Matlah Estuary (Bhakta *et al*., 2020a,b). The species is mainly found in coastal waters, estuaries and rivers and thus occurs in freshwater, brackish and marine habitats (Talwar and Jhingran, 1991; Bhakta *et al*., 2019b; 2020c). *O. pama* is distributed in the Ganga and Brahmaputra rivers and its estuaries in India, Burma, Sittang River, Malay Peninsula, Sumatra and Guinea (Talwar, 1995). Adequate studies on the reproductive biology of *O. pama* are lacking not only from the Hooghly-Matlah estuarine system of West Bengal, India but from other regions of the world as well.

The study on understanding of fish reproductive biology and strategies are very much essential for fishery management and assessment (Dinh, 2017; Hossain *et al.,* 2017). The knowledge on length at first sexual maturity in fishes is important to find out the causes of changes in maturity stages and such knowledge is an indicator of minimum allowable capture size (Templeman, 1987; Hossain *et al.,* 2017). Further, knowledge on fish fecundity *i.e*., the number of eggs produced by a fish during a year is an important aspect for estimating the spawning potential or probable stock of the species (Lagler, 1956; Kovacic, 2005). An understanding of the relationships between reproductive parameters, such as spawning periodicity, fecundity and spawning duration and fish length is required to estimate potential annual fecundity at different sizes for multiple-spawning species (Farley *et al.,* 2015). In the present study, the reproductive features of *O. pama* were investigated by microscopic observation of the gonads, observing spawning season and periodicity as well as the gonadosomatic index (GSI).

There are many studies about the reproductive biology of sciaenids from the Indian coast (Bal and Pradhan, 1945; Gopinath, 1946; Jacob, 1948; John, 1951; Prabhu, 1956; Vaidya, 1960; Annigeri, 1963; Rao, 1963; Sawant, 1963; Dutta and Thankam, 1968; Devadoss, 1969; Bhusari, 1975; Nair, 1977; Murty, 1979; Baragi and James, 1980; Muthiah, 1982; Murty and Ramalingam, 1986; Jayasankar, 1989 and 1994; Chakraborty *et al.,* 2000; Ghosh *et al.,* 2009; Manojkumar, 2011; Sandhya, 2012). But only two reports are available on larval development and spawning of *O. pama* from Hooghly Estuary and Ganga River, West Bengal (Pantulu and Jones, 1950; Motwani *et al*., 1954). However, some important parameters such as maturity stages, length at first maturity, sex ratio, spawning periodicity, ova diameter variation and fecundity of the fish are quite lacking. But such aspects are needed for promoting sustainable fisheries of concerned species in the region. Hence the present study attempted to investigate such vital aspects of the reproductive biology of the fish in Hooghly-Matlah estuarine system of India.

Materials and methods

A total of 618 samples of *O. pama* were collected at monthly intervals by local fishermen using gillnet (20-60 mm mesh size), bag net (10-15 mm cod-end mesh size), 'bhola ber' (drift gill net, targeted to catch only sciaenids) with mesh size of 15 to 70 mm, in Hooghly-Matlah estuarine system of West Bengal, India during November 2016 to April 2018. The fish samples were collected from three commercial landing sites namely, Godakhali, Diamond Harbour and Frasergung for a wider range of length-frequency data (Fig. 1). The freshly collected fish samples were brought to the laboratory after preservation in ice for reproductive studies. The sex of each individual was assessed by observation of the gonad (by noting the colour, shape and size). The total length (TL), ovary length (OL), body weight (BW) and ovary weight (OW) of the sampled specimens were determined to the nearest 0.01 mm and 0.001 g respectively. Ovaries from the ripe female were taken out and preserved in 10% formalin solution.

To estimate spawning periodicity, ova diameter measurements of intra-ovarian eggs were carried out from the preserved ovaries as per Clark (1934) and Prabhu (1956). Seventy-eight ovaries of different maturity stages were examined to study the spawning periodicity by measuring ova diameter. To assess the distribution pattern of eggs in the ovary, ova from the anterior, middle and posterior regions were examined. A total of 500 eggs were examined from each of the ovaries to minimise the possible errors in the portrayal of different stages of maturity. A digital microscope was used for studying ova diameter. The measured ova were grouped into 0.05 mm class intervals and their frequency polygons were drawn graphically.

For studying maturity and spawning season, 320 female specimens of *O. pama* ranging from 107-384 mm (195.65±38.35 mm) and 10.20-470.71 g (65.57±47.55 g) in total weight were examined. Maturity stages were recognised based on the colour, shape, size and space occupied by the gonad in the body cavity. Developmental stages and annual reproductive cycle for females were determined as immature, early maturing, late maturing, early mature, late mature, ripe and spent using the ICES (International Council for Exploration of the Seas) scale (Wood, 1930). The annual occurrence of different stages of maturity of fish during the period of investigation was depicted graphically and the spawning period was inferred from the incidence of ripe samples. The gonado-somatic index (GSI) was calculated month-wise and sex-wise using the equation (Vladykov, 1956):

$$GSI = \frac{\text{Weight of the gonad}}{\text{Total body weight}} \times 100$$

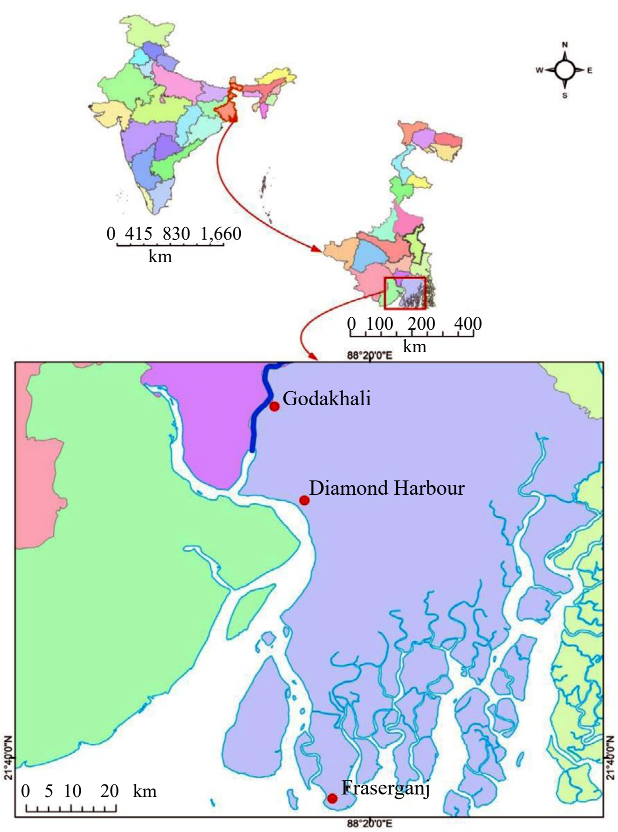

Fig. 1. Study area in Hooghly-Matlah Estuary of West Bengal

Based on the examination of the maturity stages, the length at first maturity (L_m) was determined. In this study, female specimens in stage III and above were considered as mature (Farmer *et al*., 2005). The length at which 50% of the population mature is considered as length at first maturity. It was found out graphically from the percentage of cumulative frequency curve of mature fishes against size (Udupa, 1986).

The gravimetric method was employed to determine fecundity, which is based on the relation between ovary weight and the oocyte density in the ovary (Hunter and Goldberg, 1980; Murua *et al.,* 2003). Fecundity was determined by the following formula:

$$\text{Absolute fecundity} = \frac{\text{No. of ova in the subsample}}{\text{Weight of subsample}} \times \text{Total ovary weight}$$

Relative fecundity was obtained by dividing absolute fecundity with the total weight of fish. To establish the relation of fecundity "F" (Y) with total length "TL", body weight "TW", ovary length "OL" and ovary weight "OW" the following formula (Bagenal, 1978) was used:

$$F = aL^b$$

where F is the fecundity, L is the total length of the fish in mm and 'a'and'b' are constants. It is log transferred for a linear relationship. To determine the Pearson correlation coefficient between fecundity and the total length, body weight, ovary length and ovary weight, the least square method was used.

To know the homogeneity of the distribution of sexes, variation of sex ratio with respect to months and size were analysed employing Chi-square test (Snedecor and Cochran, 1967) as:

$$\text{Chi-square} = \frac{(O\text{-}E)^2}{E}$$

where, "O" is observed frequencies and "E" is expected frequencies. The data were computed and statistically analysed using Microsoft Excel Version 2010

Results and discussion

Maturity stages

The gonads of *O. pama* are bi-lobed, united in the middle and opening out through a common duct. They are attached in the dorsal portion of the body cavity with close association with kidneys. The female ovaries are easily differentiated into seven successive maturity stages (Table 1). Results of 320 females collected during 18 months period were examined for maturity stages and pooled for one year and depicted in Fig. 2.

Maturity stages of females (stage III to VII) were recorded during all the months. A maximum percentage of ripe gonads were observed during the months of February-March and September-November indicating two peak spawning seasons of the species (Fig. 3 and 4). The maximum quantity of spent females (stage VI) were recorded during November (11.36%) and December

Fig. 3. Gonads of *O. pama* (female) showing different stages of maturity

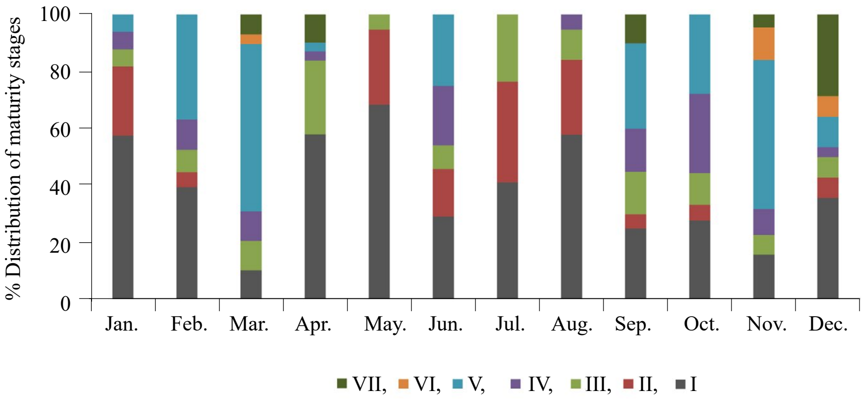

Fig. 2. Month-wise percentage distribution of maturity stages (female) in *O. pama*

Table 1. Key features to the maturity stages in the female of *O. pama*

Maturity stages	State of maturity	Nature and occupancy of ovary in body cavity	Appearance of ova under the microscope
I	Immature	Ovary creamy in colour, extends up to 1/3 of the body cavity, ova not visible through the naked eye	Small, without yolk, transparent, nucleus prominent
II	Immature	Ovary dark creamy colour, occupancy up to 1/3 to ½ of the body cavity, ova visible to naked eye	Formation of yolk just started around the nucleus
III	Maturing	Colour of ovary pink, creamy, extends up to ½ to 2/3 of the body cavity	Ova very small, semi-opaque, yolk fully covered the nucleus
IV	Maturing	Ovary creamy to light yellowish, blood vessels visible, extends up to 2/3 of the body cavity, ova visible	Ova opaque in nature, attached to the follicular cells
V	Mature	Ovary reddish yellowish, blood vessels very prominent, extends up to 3/4 to the full body cavity, ova very clear	Highly opaque ova, not attached with the follicle
VI	Ripe	Ovary reddish, extends up to full body cavity, ova can be seen from the ovarian wall	Ova ripe and enlarged, transparent, yolk sac with oil globules
VII	Spent	Ovary shrunken in nature, pale blood or pale creamy in colour	-

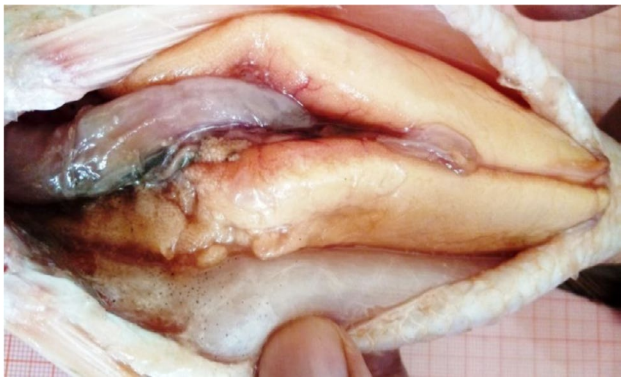

Fig. 4. Fully mature ovary of *O. pama*

(7.14%), subsequent to the spawning months. The immature stages (stage I and II) of females were found almost throughout the year except in March.

Length at first maturity (L_m) and sex ratio

To estimate the L_m, both male and female of stage III (large and whitish testis and yellowish-orange ovaries) and onwards were taken into consideration and a maturity curve was plotted. The length at maturity was estimated as 183 and 196 mm for males and females respectively. It was observed that the male population attained sexual maturity at smaller sizes than that of females (Figs. 5 and 6).

A total of 618, *O. pama* were collected during the study period with size ranging from 100-384 mm and 7.29-470.71 g, respectively. Monthly sex ratio (M:F) varied from 1:0.61 to 1:2.32. In the present observation, the sex ratio obtained for *O. pama* indicated the marginal predominance of the female population over males (Table 2). Female populations dominated in the months of January-February (1:1.14-1:2.24), July-December (1:1.13-1:1.17), while males dominated during March-June (1:0.73-1:0.71) (Fig. 7). Sex ratio of male to female was 1:1.07, without any significant difference from the expected 1:1 ratio (χ^2 = 0.783, df = 1, p>0.05). The occurrence of more female specimens during February and November in the present study coincides with the peak spawning of *O. pama* occurring in the Hooghly-Matlah estuarine system. The species might migrate to the estuarine habitat during these periods for spawning.

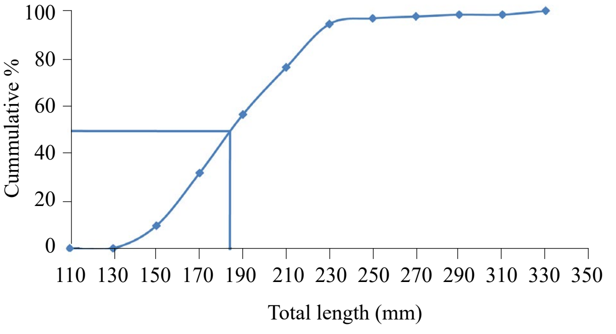

Fig. 5. Length at first maturity (male)

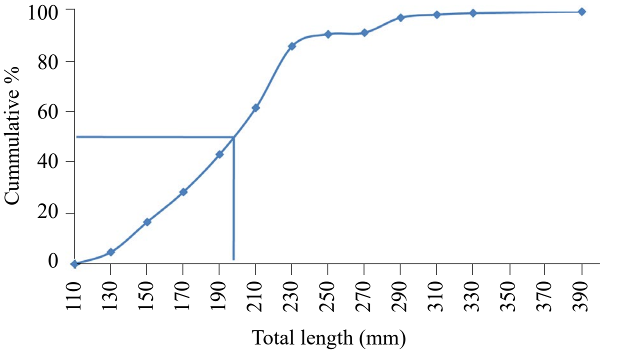

Fig. 6. Length at first maturity (female)

Table 2. Month-wise distribution of male and female *O. pama* and variations in their sex ratio

Months	No. examined	Males	Females	% Males	% Females	Expected	Sex ratio (M:F)	Chi square value
Jan.	62	29	33	46.77	53.23	31	1:1.14	0.258
Feb.	55	17	38	30.91	69.09	27.5	1:2.24	8.018
Mar.	69	40	29	57.97	42.03	34.5	1:0.73	1.754
Apr.	74	43	31	58.11	41.89	37	1:0.72	1.946
May	50	31	19	62.00	38.00	25	1:0.61	2.880
Jun.	58	34	24	58.62	41.38	29	1:0.71	1.724
Jul.	32	15	17	46.88	53.13	15.5	1:1.13	0.125
Aug.	31	12	19	38.71	61.29	15.5	1:1.58	1.581
Sept.	39	19	20	48.72	51.28	19.5	1:1.05	0.026
Oct.	33	15	18	45.45	54.55	16.5	1:1.20	0.273
Nov.	63	19	44	30.16	69.84	31.5	1:2.32	9.921
Dec.	52	24	28	46.15	53.85	26	1:1.17	0.308
Total	618	298	320	48.22	51.78	309	1:1.07	0.783

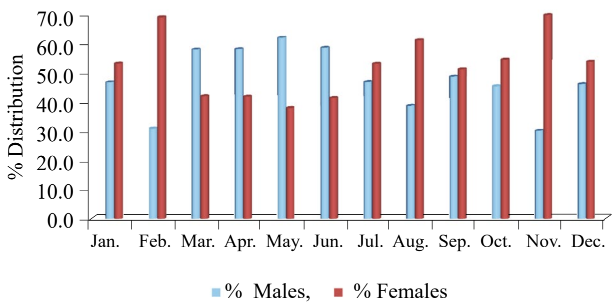

Fig. 7. Month-wise percentage distribution of male and female *O. pama*

In the present study, *O. pama* attained sexual maturity at the size of 183 mm for males and 196 mm for females, respectively. A comparatively higher length at first maturity was reported by Ayyapan *et al.* (2011) and Bhakta *et al.* (2015) for *O. pama* with the length of the female 154 mm from both Hooghly and Narmada estuaries (Table 3). A relatively higher length class of 1100 mm and 1200 mm at first maturity of female *O. biauritus* was reported by Ghosh *et al*. (2009) and Kutty (1967) from Diu and Mumbai waters respectively. The size at first maturity may vary in aspects of respective environments, number of population, food availability and estimated length frequency (Hossain *et al.,* 2017).

In this study, the sex ratio obtained for *O. pama* indicated relatively more female population compared to male; which is in agreement with earlier studies in sciaenids from India, like Murty (1979) in *J. carutta* (1:1.1), Fennessy (2000) in *O. ruber* (1:1.8), Telvekar (2006) in *J. sina* (1:1.6) and Sandhya (2012) in *O. cuvieri* (1:1.1). The reason may be that the male population remains in the deeper waters, especially in the middle of the estuary, whereas the females migrates near the shore

Table 3. Length at first maturity (L_m) of *Otolithoides* spp. and *Otolithes* spp. reported by other researchers

Species	LM (mm)	Location	Author	Methodology used
Otolithes ruber	200	Mumbai	Devadoss (1969)	By the cumulative frequency, length at which 50% of the individuals became mature.
Otolithes cuvieri	195	Mumbai	Gulati (1987)	-do-
O. cuvieri	170	Mumbai	Rao *et al.* (1992)	-do-
O. cuvieri	160	Veraval		-do-
O. cuvieri	120	Calicut		-do-
O. cuvieri	256	Veraval	Raje (2000)	
O. cuvieri	218	Veraval	Chakraborty *et al.,* 2000	-do-
O. cuvieri	170	Mumbai	Chakraborty *et al.* (2000)	-do-
O. ruber	175	Mumbai	Chakraborty *et al.* (2000)	-do-
O. cuvieri	270	Mumbai	Telvekar (2002)	-do-
Otolithoides pama	154	Hooghly Estuary	Ayyappan *et al.* (2011)	-
Otolithoides biauritus	1101.5	Vanakbara, Diu	Ghosh *et al.* (2009)	-do-
O. cuvieri	196	Ratnagiri	Sandhya (2012)	-do-
O. pama	154	Narmada Estuary	Bhakta *et al.* (2015)	-

which is also supported by the works of Barbosa *et al.* (2012). According to Rao *et al.* (1992), the sex ratio in different species of sciaenids was not uniform but varied from month to month and season to season, which agrees with the results of the present study. This happens because of the differential behaviour of sexes, environmental conditions and fishing (Bal and Rao, 1990). Velip and Rivonker (2018) observed that, in *J. borneensis* and *O. ruber* inhabiting in Goa, migration patterns mainly depend on search of potential spawning grounds. The sex ratio reported in sciaenids occurring in different water bodies is provided in Table 4.

In general, while investigating biological parameters of fishes, the dominance of either sex is observed and this may be due to schooling behaviour, differential accessibility, vulnerability, growth, maturity and mortality (Hoda and Ajazuddin, 1992). The different pattern of migration of males and females to the respective fishing ground leads to exploitation of either males or females at a particular time which may result in various sex ratios (Ghosh *et al.,* 2016). The metabolic strain of spawning is considered to be more in older and senescent males than the females and could result in an excess of females at spawning except for the earlier maturation of males (Cooper, 1983). In general, the sex ratio in most species of fish is 1:1, which mainly depends on food availability in the respective environment and favouring female over the male if sufficient food is available (Nikolsky, 1963).

Spawning periodicity using ova diameter

For ova diameter studies, a total of 78 ovaries of *O. pama* of different maturity stages were examined and the pooled ova diameter frequency polygons are depicted in Fig. 8. The maturity stages of the ovary were divided into seven stages, though in the 7th stage (spent) no measurable ova were noticed. The matured ovaries of *O. pama* contained both mature and maturing ova which indicated that the species was a batch or asynchronous spawner. The first batch of the ova measured from 65 to 75 mm, the second batch from 50 to 60 mm and 3rd batch from 30 to 40 mm in diameter. The largest size of the yolked ova was noticed during March, June and November which indicated the peak spawning season of the species.

In the present study, it was found that *O. pama* spawned throughout the year with three distinct spawning periods which was confirmed by the evidence of three modes of ova diameter frequency. In multiple spawning sciaenids there will be more than one mode in ova diameter frequency which is supported by the works of Hoda and Ajazuddin (1992) in *J. elongatus*; Sandhya (2012) in *O. cuvieri*; Nair (1977), Dukhande (1991), Jayasankar (1994) and Kumar *et al.* (2012) in *Johnieops sina*. Baragi and James (1980) found 3 batches of eggs in a year from *J. osseus* (Day), presently known as *J. dussumieri* (Cuvier 1830) from the South Kanara coast of India. The spawning season of fish is directly related to the size progression of ova in different months and is supported by the works of Ghosh *et al.* (2009) in *O. biauritus*.

Pantulu and Jones (1950) while studying the larval development of the Gangetic whiting, *Pama pama* mentioned that the species breeds throughout the year in Hooghly-Matlah estuarine system, as the evidence of larval stages of the species was found year round. According to David (1954), *P. pama* breeds almost throughout the year close to or within the Hooghly Estuary and spawning was first obtained during April and May.

Table 4. Sex ratios of sciaenids reported from different water bodies

Species	Author	Location	Sample size	Sex ratio (M: F)
Johnius carutta	Murty (1979)	Kakinada, India	-	1:1.1
J. dussumieri			-	1:1.2
Atrobucca nibe	Murty (1980)	Kakinada, India	-	1.7:1.0
Otolithes cuvieri	Hoda and Ajazuddin (1992)	West Wharf Fish Harbour, Pakistan	513	1.5:1.0
J. elongatus			663	1:1.2
Otolithes ruber	Fennessy (2000)	KwaZulu-Natal coast, South Africa	1516	1:1.8
A. nibe			818	1:3.6
J. dussumieri			1360	1:1.3
J. amblycephalus			1254	1:1.1
J. sina	Telvekar (2006)	Mumbai waters, India	515	1:1.6
Otolithoides biauritus	Ghosh *et al.* (2009)	Vanakbara, Diu, India	455	1:1.1
J. sina	Manojkumar (2011)	Malabar coast, India	5503	1:0.9
O. cuvieri	Sandhya (2012)	Ratnagiri waters, India	788	1:1.1
J. sina	Kumar *et al*. (2012)	Ratnagiri waters, India	1031	1:0.9

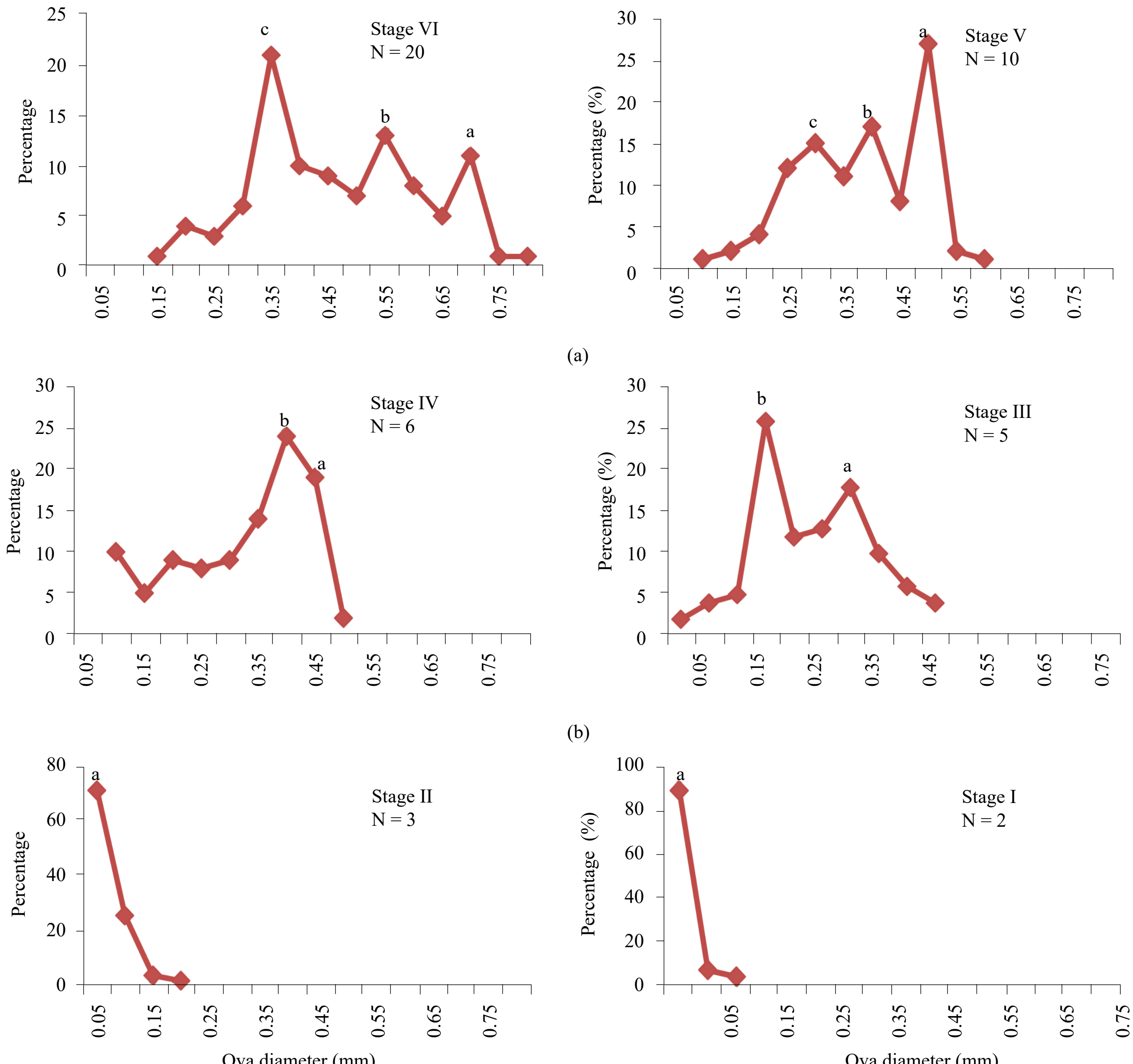

Fig. 8. Ova diameter frequency of *O. pama* from stage I to stage VI in the Hooghly-Matlah Estuary of West Bengal, India ('a', 'b' and 'c' indicating batches of ova in the ovary)

Spawning season

The spawning season of *O. pama* in Hooghly-Matlah Estuary was observed almost throughout the year with three distinct peaks, one during February-March; second during June and third during September-November. The monthly mean value of GSI for both males and females *O. pama* is depicted in Fig. 9. A relatively higher mean GSI values for both males and females were observed during the month of February-March, June and September-December, which indicated the prolonged spawning activity of the species. The monthly mean GSI values for the male ranged from 0.44±0.14 (December) to 1.40±0.46 (March). In the case of females, the monthly mean GSI value ranged from 0.56±0.12 (August) to 10.14±4.93 (March).

According to Pantulu and Jones (1950) and Motwani *et al.* (1954), pama croaker breeds throughout the year in Hooghly Estuary and Ganga River respectively, which supports the present findings (Table 5). Bhatt *et al.* (1964) mentioned that other species from the genus *Otolithoides* *i.e.*, *O. biauritus* showed prolonged spawning season with a peak during May or June from Saurashtra coast of India. Recently Ghosh *et al.* (2009) also found that *O. biauritus* breeds round the year with the peak from May to August at Vanakbara, Diu of India.

Table 5. Spawning season of *Otolithoides* spp. and *Otolithes* spp. reported from Indian waters

Species	Spawning periodicity	Spawning season	Location	Author
Otolithoides pama	Throughout the year	Round the year	Hooghly Estuary	Pantulu and Jones (1950)
Otolithoides pama	Almost round the year		Ganga River	Motwani *et al.* (1954)
Otolithes argenteus	Once in a year	October-January		Annigeri (1963)
Otolithoides biauritus	Prolonged spawning	May or June	Saurashtra coast	Bhatt *et al.* (1964)
Otolithes ruber	Once in a year	July to October	Bombay	Devadoss (1969)
Otolithes cuvieri	Once in a year	February-May	Veraval waters	Chakraborty *et al.* (2000)
Otolithes cuvieri	Once in a year	July, December	Mumbai waters	Chakraborty *et al.* (2000)
Otolithoides biauritus	Throughout the year	(May to August peak)	Vanakbara, Diu	Ghosh *et al.* (2009)
Otolithes cuvieri	Throughout the year	April	Ratnagiri	Sandhya (2012)
Otolithoides pama	Almost round the year	February-March, June and October-November	Hooghly-Matlah Estuary	Present study

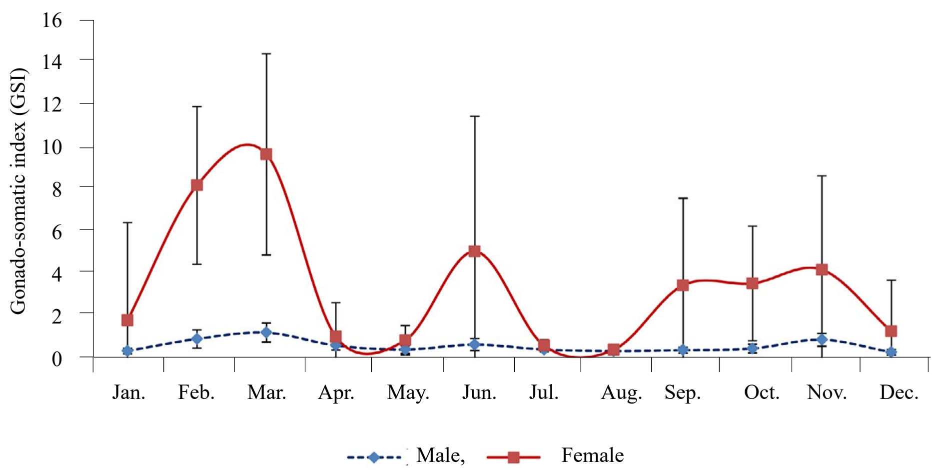

Fig. 9. Month-wise gonado-somatic index of *O. pama*

Yamaguchi *et al*. (2006) observed that the spawning season of *Pennahia argentata* extended from April to September with a peak in May to August from the Ariake Sound waters of Japan. The reproductive activity of South American silver croaker *Plagioscion squamosissimus* was reported throughout the year with the peak during February/March and August/September in the Para River Estuary (Amazon Estuary) by Barbosa *et al.* (2012). Militelli *et al.* (2013) studied the reproductive biology of Sciaenid species in the coastal zone of Argentina and reported that species like *Micropogonias furnieri, Cynoscion guatucupa* and *Macrodon ancylodon* spawn from October to March (six months) while *Pogonias cromis* from October to December (three months). Zhang *et al.* (2019) studied the reproductive biology of *Johnius taiwanensis* in Fujian waters, Southern China and reported that spawning activity for females and males lasted from April to October with peak spawning months for females being July to September.

There are no reports on GSI of this species, which restricts our ability to compare our findings. While studying the GSI of *Otolithoides biauritus* (another genus of *Otolithoides*) from Diu along the west coast of India, Ghosh *et al.* (2009) mentioned that the values increased from January and attained a peak during May, after which it decreased from September to December which slightly differs from the present findings. Kumar *et al.* (2012) studied GSI values of *J. sina* and reported the highest values from February to April and in September to November, which suggests that the species had two breeding peaks, which resembled our findings for *O. pama*.

Fecundity

A sample of 78 mature females with a total length and weight varying from 107 to 330 mm and 10.2 to 325.1 g respectively was studied. The length of the ovary examined for fecundity estimation varied from 31 to 110 mm with a corresponding weight range of 1.5 to 29.49 g. The absolute fecundity ranged from 4652 to 170688 eggs (mean 24950±32441.2). Relative fecundity varied from 96 to 808 eggs g^{-1} body weight (mean 382±176.83) and from 2040 to 6971 eggs g^{-1} ovary weight (average

4139±1142.05). Fecundity of fish exhibited a significant correlation ($p<0.05$) with total length ($r=0.736$), body weight ($r=0.876$), ovary length ($r=0.860$) and ovary weight ($r=0.973$) of fish.

A linear relationship between fecundity (F) and other parameters such as total length (TL), total weight (TW), ovary length (OL) and ovary weight (OW) of the fish (Fig. 10a, d) was established after log transformation for convenience and presented as follows:

a) $y = 2.404\ x - 1.204$ ($R^2 = 0.0.544$)
where, y = log fecundity and x = log TL

b) $y = 0.855\ x + 2.778$ ($R^2 = 0.650$)
where, y = log fecundity and x = log TW

c) $y = 2.540\ x - 0.174$ ($R^2 = 0.697$)
where, y = log fecundity and x = log OL

d) $y = 1.105\ x - 3.539$ ($R^2 = 0.892$)
where, y = log fecundity and x = log OW

For successful fisheries management, accurate assessment of fecundity is crucial to recognise the revival ability of fish populations (Lagler, 1956; Hossain *et al.*, 2017). There were no reports on the estimated fecundity of *O. pama*; hence the present findings were compared with the literature available on other *Otolithoides* and *Otolithes* spp. (Table 6).

Devadoss (1969) reported that absolute fecundity of *O. ruber* ranged from 44,621 to 1, 79,659 in Bombay waters. A few reports are available regarding the fecundity estimation of *O. cuvieri* from Indian waters. Chakraborty (1988) reported the range of 1, 21,445 to 1, 85,786 eggs from Bombay waters, while Rao *et al.* (1992) reported that the number varied from 1, 05,454 to 3, 55,913 eggs from Veraval waters. Telvekar (2002) reported a range of 3,06,769 to 3,57,871 eggs from Bombay waters. In recent years, Sandhya (2012) reported that the absolute fecundity ranged from 1, 12,350 to 6, 30,500 eggs in *O. cuvieri* having ovary weight between 5.51 to 26.0 g collected from Ratnagiri waters of Maharashtra. Telvekar (2002) estimated absolute fecundity of *O. cuvieri* from Bombay waters in the range 3,06,679 to 3,62,030 eggs in fishes of length ranging from 305 to 343 mm .

Kutty (1967) estimated the fecundity of *O. biauritus* to be more than 6 million ova. Ghosh *et al.* (2009) reported absolute fecundity of *O. biauritus* as between 1,82,020-1,94,1400 eggs from Diu waters. The relative fecundity ranged between 42.3 to 121.3 eggs with an average of 65.7 per g body weight. They also mentioned that the number of eggs released generally increased with the weight and size of the respective species. In their

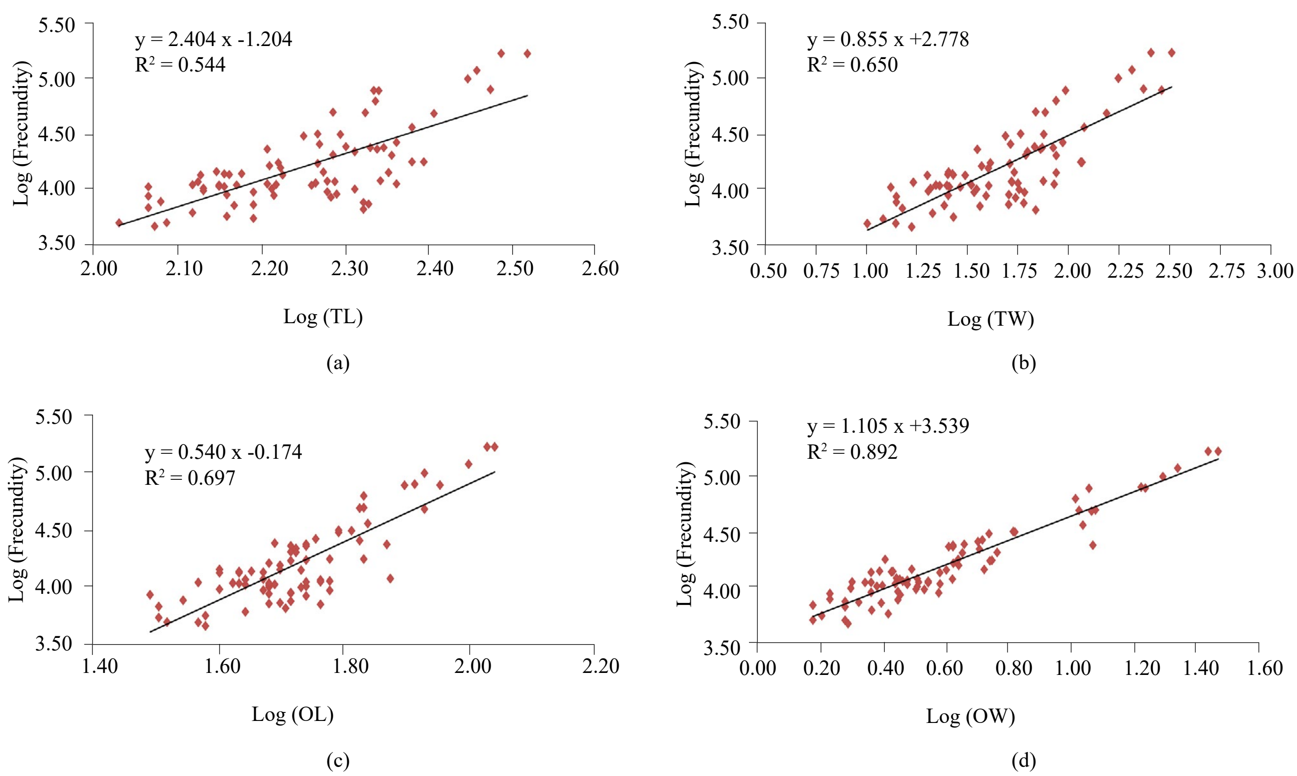

Fig. 10. Logarithmic relationship between fecundity (F) and (a) total length (TL), (b) total body weight (BW), (c) ovary length (OL) and (d) ovary weight for female *O. pama* collected from Hooghly-Matlah Estuary of West Bengal, India during November 2016 to April 2018

Table 6. Fecundity of *Otolithoides* spp. and *Otolithes* spp. reported from Indian waters

Species	Absolute fecundity	Relative fecundity	Location	Author
Otolithes ruber	44,621-1,79,659	237-620	Bombay	Devadoss (1969)
Otolithes cuvieri	1,21,445-1,85,786	-	Bombay	Chakraborty (1988)
O. cuvieri	1,05,454-3,55,913	-	Veraval	Rao *et al.* (1992)
O. cuvieri			Veraval	Chakraborty *et al.* (2000)
O. cuvieri			Mumbai waters	Chakraborty *et al.* (2000)
Otolithes ruber			Mumbai waters	Chakraborty *et al.* (2000)
Otolithes cuvieri	3,06,769-3,57,871	-	Bombay	Telvekar (2002)
Otolithoides biauritus	1,82,020-1,94,1400	42.3-121.3	Vanakbara, Diu	Ghosh *et al.* (2009)
Otolithes cuvieri	1,12,350-6,30,500	814-2278	Ratnagiri	Sandhya (2012)

study, fecundity exhibited significant correlation ($p<0.01$) with total length ($r=0.90$) and body weight ($r=0.91$).

Rao (1963) reported a linear relationship between fecundity and ovary weight of a sciaenid species *Pseudosciaena diacanthus* from Bombay waters. Kumar *et al.* (2012) observed linear relationship in *J. carutta* between fecundity and ovary as well as body weight at Visakhapatnam, south-east coast of India. Several factors strongly influence the fecundity of the fish species. According to Bagenal (1978), fecundity generally varies with fertility, spawning frequency, egg size, density of the population and environmental factors. Bromage *et al.* (1990) also mentioned that fecundity of the fishes may vary among populations and at times between strains of fish species.

The present study is a pioneering work on reproductive parameters of *O. pama* in Hooghly-Matlah estuarine system, West Bengal as well as for the Indian coast. The pama croaker was found to be a batch or multiple spawner with high fecundity, males generally matured at sizes smaller than females and female populations show marginal dominance over male population. For fisheries management and assessment, it is pre-requisite to have detailed knowledge on reproductive parameters of respective species. Being a tropical estuary with rich fish diversity and a multi-gear fishery, management is not an easy task. The information on length at first maturity, fecundity, spawning periodicity and season of *O. pama* will be quite useful for local policymakers to set the optimum size limit of fish catch and time of fishing in the area. It will be helpful for the sustainable management and conservation of this commercially important species in estuarine ecosystems.

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