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Research Article

Reproductive Biology of the Catfish *Pachypterus atherinoides* (Bloch, 1794) with Special Reference to Its Lentic and Lotic Ecosystems

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ABSTRACT

The study of reproductive biology is extremely crucial in fishery. *Pachypterus atherinoides* (Bloch, 1794) is a good food as well as an ornamental catfish in the World. The present study aims to examine the seasonal reproductive behavior of *P. atherinoides* regarding both its lentic and lotic ecosystems. The study was conducted over two years in selected lentic and lotic aquatic ecosystems of the Jhargram and Paschim Medinipur districts of West Bengal, India using the seasonally observed gonadosomatic index (GSI), fecundity, and gonad maturation stages for both habitats in the study area. The study reveals *P. atherinoides* to show single annual spawning between June-September. No significant difference was found regarding breeding period in terms of lentic and lotic aquatic ecosystems. This study can help aquaculturists regarding the culture, captive breeding, and conservation of *P. atherinoides*, as well as researchers regarding the biometric study of another fish.

Keywords: Fecundity, gonadosomatic index, gonad maturation, lentic, lotic, *Pachypterus atherinoides*

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INTRODUCTION

Fish reproductive biology entails gonad maturation, spawning period, spawning frequency, fecundity, and sexual development. Breeding biology, maturation, and fecundity are investigated in order to provide data that can be useful regarding fish conservation. The frequency of spawning in a year for a specific fish species can be determined by knowing its spawning periodicity. The significance of fecundity is self-evident, as it indicates the number of eggs that are laid. Understanding the fecundity of fish facilitates setting the arrangements for effectively hatching eggs on a fish farm. This type of research is also critical in fishery management. Fundamental themes in fish biology also include the description of reproductive techniques and the study of fecundity. For one to understand a fish's life history, spawning, culture, and administration, one also needs to understand fish reproduction. Reproductive strategies are one of the most important aspects of stabilizing a population in an environment. Examining the stages of gonad development for each fish, such as the period of the spawning season and the size at first maturity, is necessary for studying fish reproduction. The study of reproductive behavior has focused primarily on fish fecundity and the gonadosomatic index (GSI). The GSI is a key component of fish biology and aids in identifying the fish mating season by offering a full grasp of fish reproduction and the reproductive condition of each species (Shankar & Kulkarni, 2005). Fecundity is the quantity of maturing eggs a female has before spawning (Bagenal, 1978). Having a comprehensive understanding of fecundity is important for estimating the commercial potential of fish stocks and the spawning stock's abundance and reproductive potential (Lagler et al., 1956). *Pachypterus atherinoides* (Bloch, 1794), often known as Indian potasi, is a common catfish belonging to the family Schilbeidae and is found in rivers and ponds throughout India (except Kerala), Pakistan, Bangladesh, Nepal, Myanmar, and Bunna (Menon, 1999). It has high nutritional as well as ornamental value. The fish meal of the species contains 343 Kcal in energy, 16 g of water, 58 g of protein, 9 g of fat, and 17 g of minerals (primarily 1,597 mg of calcium, 595 mg of phosphorus, and 41 mg of iron) per 100 g (Gopalan et al., 2004). Aquarists are attracted to it because of its bright color and small size. This species has been gradually decreasing due to pollution, habitat destruction, selective captive breeding, and removal from aquatic bodies due to their carnivorous nature, as well as the high demand for exotic catfish (African catfish *Clarius gariepinus* [Burchell, 1822]; Thai catfish *Pangasius sutchi* [Fowler, 1937]). The world has seen very little research on the reproductive biology of *Pachypterus atherinoides* (Bloch, 1794). India has yet to have a study on the reproductive biology of *Pachypterus atherinoides*. Gogai et al. (2020) and Jana et al. (2024) only studied this species' feeding biology. Gosavi et al. (2020) studied the reproductive biology of *Pachypterus khavalchor* in the Panchaganga River of Western Ghat, India. Various researchers (Dasgupta, 2004; Chattopadhyay et al., 2014; Paul and Chanda, 2017; Gupta, 2015; Jana et al., 2021A; Jana et al., 2021B; Jana et al., 2022A; Jana et al. 2022B; Sit et al. 2020; Chanda and Jana., 2021; Sahil et al., 2023; Sit et al. 2022A; Sit et al. 2022B; Sit et al., 2023A; Sit et al., 2023B; Jana et al., 2024) have also studied some aspects of various indigenous fish species in West Bengal, but none of these observed the reproductive behavior of *Pachypterus atherinoides*. Therefore, the present study will depict the seasonal reproductive biology of two different habitats that will be important for the conservation and propagation of this species.

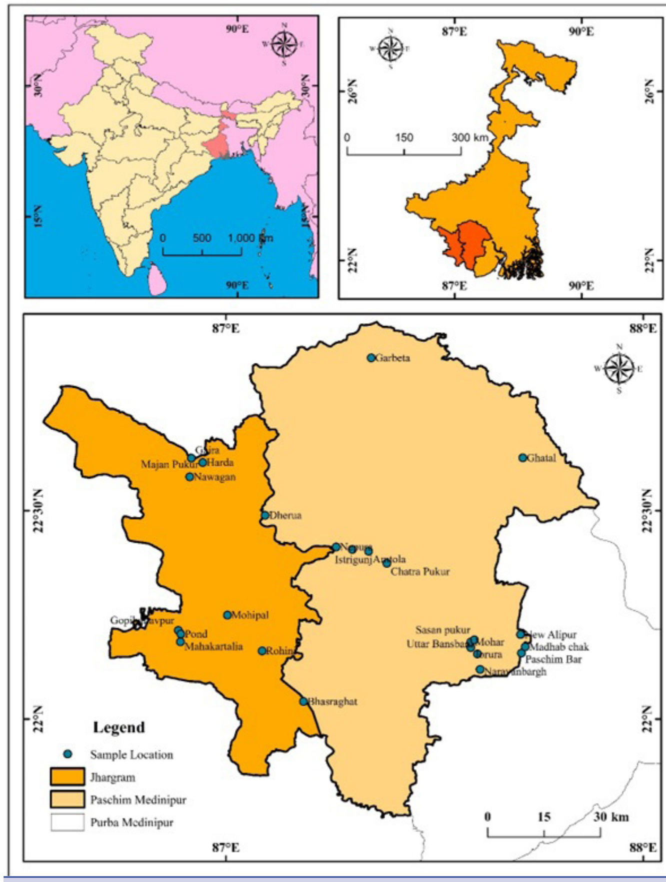

Figure 1. Specimen collection sites.

MATERIALS AND METHODOLOGY

Collection of fish specimens: Specimens were collected every 15 days from the selected lentic (ponds) and lotic (river sites) habitats of the Paschim Medinipur and Jhargram districts of West Bengal, India, during the pre-monsoon (March-June), monsoon (July-Oct), and post-monsoon (Nov-Feb) seasons between March 2020-February 2022 (Figure 1).

Sex determination: Male and female specimens were identified based on genital papilla, with males having a distinct extended papilla (Figure 2).

Length and Weight Measurements: Seasonally and ecosystem/habitat-wise, each specimen's total weight and length were measured using a digital scale with 0.01 g accuracy and a digital slide caliper with 0.01 mm accuracy, respectively.

Dissection and Internal Organ Measurement: Gonads were collected by dissection with the help of scissors, forceps, needles, and a brush. Digital slide calipers were used to measure the length, and an electronic balance was used to weigh each gonad.

Gonadosomatic Index (GSI): Howaida et al.'s (1998) formula was used to determine the GSI as follows:

$$GSI = \frac{Weight\ of\ gonad}{Weight\ of\ fish} \times 100 \quad (1)$$

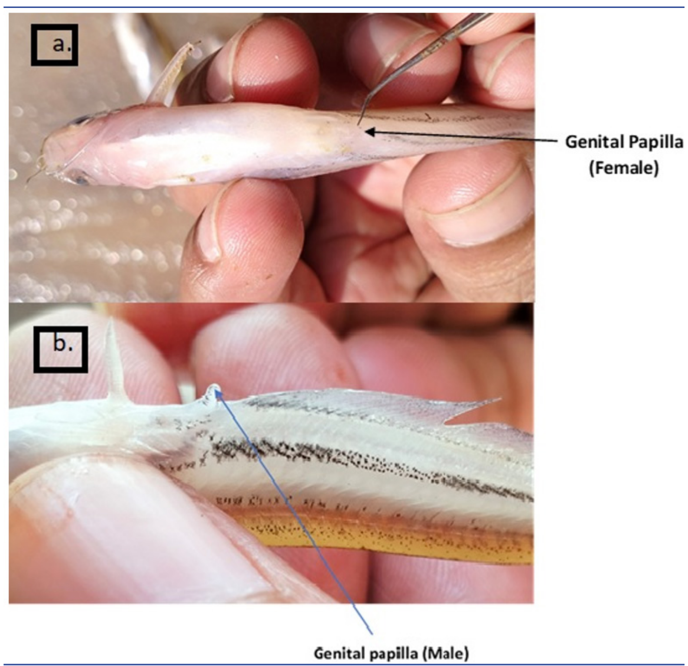

Figure 2. Genital apparatus of *P. atherinoides*. a.) Female; b.) Male.

Fecundity: The egg sac's front, middle, and posterior regions were divided into equal numbers of mature and immature eggs, which were then separated and counted using a needle and magnifying glass for each portion. The total number of eggs (i.e., the fish's fecundity) is measured using Dewan and Doha's (1979) gravimetric method as follows:

$$F = n\,G / g \tag{2}$$

where F is fecundity, n is the number of eggs in the subsample, G is the total weight of the ovary, and g is the weight of the subsample in grams.

Observed gonad maturation: Examinations were carried out at the macro and microscopic (Model-XSP L101) levels to examine both species' cycles of gonad maturation. Female and male gonad maturation stages have been divided into the various stages of development (Heins & Baker, 1988; Gomes & Araaujo, 2004; Gupta & Banerjee, 2013).

Data Analysis: Lastly, the study analyzed the data using the Microsoft Excel (2019), SPSS (2021), and Origin Pro (2023) software systems.

RESULTS AND DISCUSSION

GSI values were highest during the monsoon season ($GSI_{J\text{-}Lentic}$ = 20.29 ± 6.926 and $GSI_{PM\text{-}Lentic}$ = 19.94 ± 8.075; $GSI_{J\text{-}Lotic}$ = 20.72 ± 6.29 and $GSI_{PM\text{-}Lotic}$ = 20.50 ± 7.56) followed by pre-monsoon ($GSI_{J\text{-}Lentic}$ = 16.02 ± 4.77 and $GSI_{PM\text{-}Lentic}$ = 15.166 ± 4.52; $GSI_{J\text{-}Lotic}$ = 16.06 ± 4.65 and $GSI_{PM\text{-}Lotic}$ = 15.99 ± 4.91), post-monsoon ($GSI_{J\text{-}Lentic}$ = 8.85 ± 1.24 and $GSI_{PM\text{-}Lentic}$ = 8.52 ± 2.00; $GSI_{J\text{-}Lotic}$ = 8.65 ± 1.46 and $GSI_{PM\text{-}Lotic}$ = 9.05 ± 1.56) in both habitats of the two districts (Table 1 & Figures 3-4). The maximum GSI in both habitats occurred from June to September, with the peak value occurring in July for the lentic habitats and August for the lotic habitats, while the lowest value was in December for both habitats (Figures 5-6). The GSI values indicate the breeding season to occur between June-September for *P. atherinoides*. Hossian et al. (2019) reported the GSI to be high between April-June and very low between January-March, with the spawning season from April to June peaking in April and being at its lowest in May for the *P. atherinoides* from Kangsha River in Bangladesh. Paul et al. (2021) observed the same result as Hossian et al. (2019): After GSI peaked in April, it gradually decreased up to July. However, the present findings are not related to these two works due to the different physicochemical parameters. The current study measure fecundity as 482 ± 203.02 (4.44g -6.57g TW) and 492 ± 236.91 (4.31g -6.85g TW) for the respective lentic and lotic areas of Jhargram district; while this was measured as 526 ± 243.32 (4.23g -6.77g TW) and 538 ± 245.12 (4.36g -6.83g TW) for Paschim Medinipur's respective lentic and lotic areas (Table 2). Hossain et al. (2019) reported fecundity values of 1541-10,043 (2.33-5.59 g), while Paul et al. (2021) observed values of 1,805.17 ± 965.71 to 4,553.07 ± 1,755.36 for the *P. atherinoides* from Bangladesh. Gosavi et al. (2020) measured absolute fecundity to varied between 932-24,642 eggs/fish and relative fecundity to range between 226-

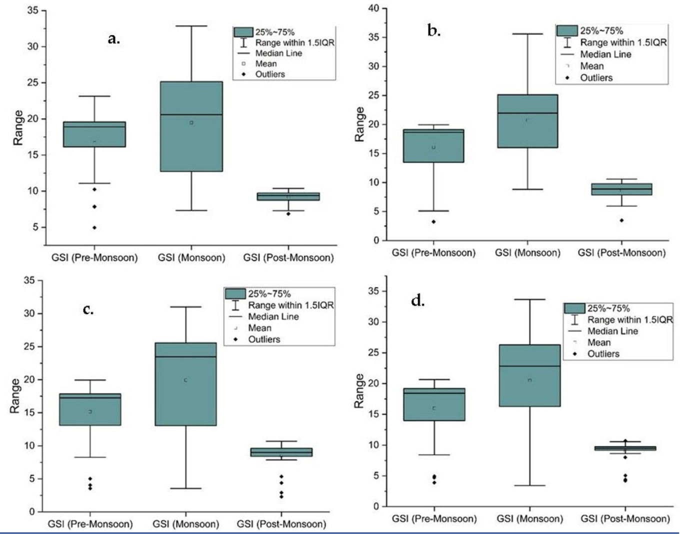

Figure 3. Seasonal GSI values of *P. atherinoides* in Jhargram (a & b) and Paschim Medinipur (c & d) districts: a & c are ponds; b & d are rivers.

Table 1. Seasonal GSI of *P. athertenoides* for both lentic and lotic habitats in Jhargram and Paschim Medinipur districts (N = 128)

District	Habitat	Season	GSI			
			Min.	Max.	Mean	SD
JHARGRAM	Pond	*Pre-monsoon*	4.60	23.14	16.0244	4.77928
		Monsoon	7.33	32.87	20.2942	6.92698
		Post-monsoon	4.73	10.38	8.8555	1.24614
	River	*Pre-monsoon*	3.25	19.93	16.0655	4.65761
		Monsoon	8.82	35.60	20.7204	6.29151
		Post-monsoon	3.48	10.57	8.6504	1.46845
PASCHIM MEDINIPUR	Pond	*Pre-monsoon*	3.55	19.97	15.1664	4.52530
		Monsoon	3.55	31.02	19.9467	8.07572
		Post-monsoon	2.30	10.70	8.5228	2.00369
	River	*Pre-monsoon*	3.90	20.64	15.9921	4.91183
		Monsoon	3.44	33.67	20.5057	7.56303
		Post-monsoon	4.21	10.70	9.0554	1.56233

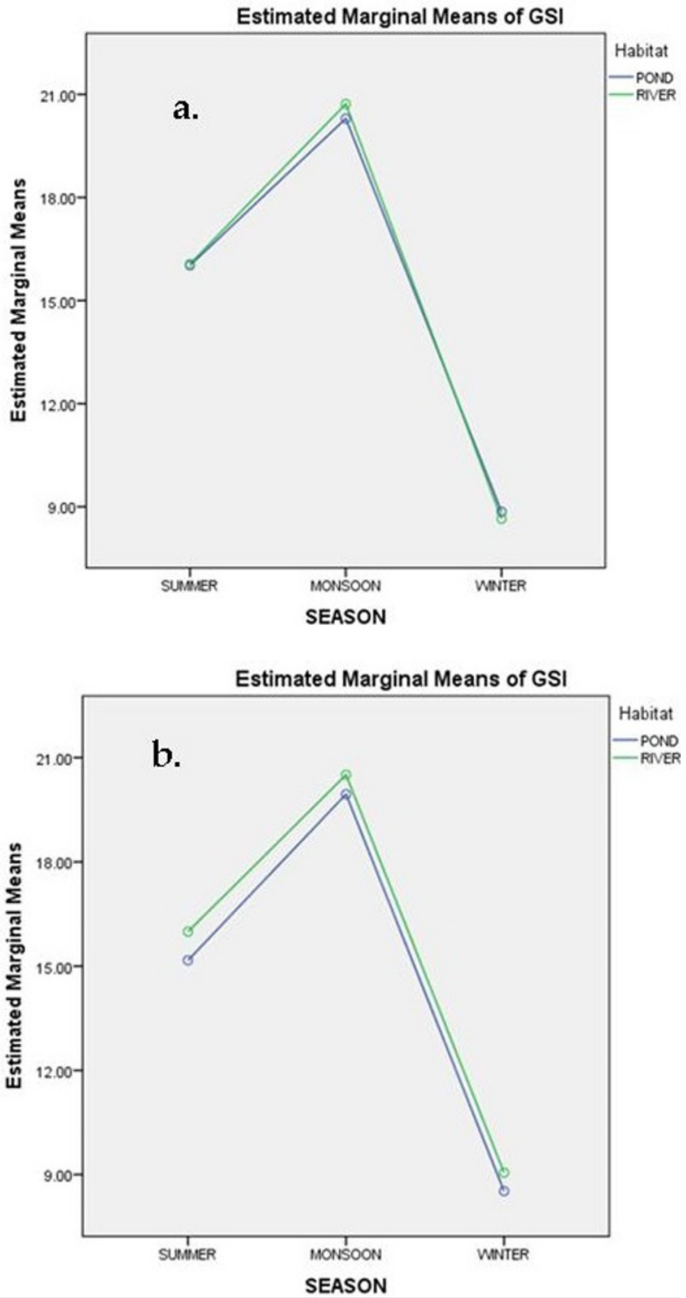

Figure 4. Seasonal variation of GSI for *P. atherinoides* in both habitats of Jhargram (a) and Paschim Medinipur (b) districts.

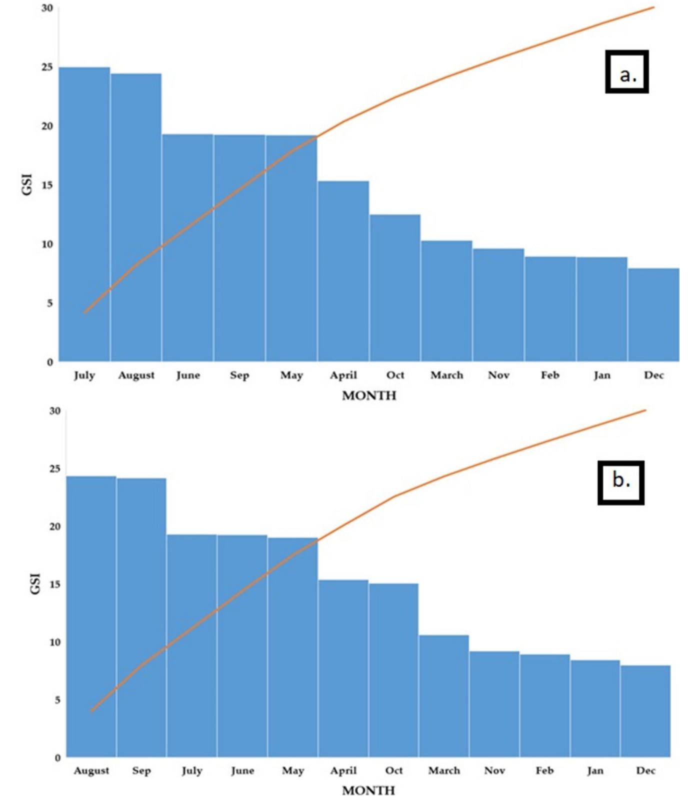

Figure 5. Monthly variation of GSI for *P. atherinoides* in the Jhargram district's: a.) ponds; b.) rivers.

723 eggs/g of body weight for *Pachypterus khavalchor*. The study's measured fecundity values are lower than those from previous studies. The R^2 values between gonad weight and fecundity were measured as 0.850 and 0.9047 for Jhargram's lentic and lotic areas and as 0.738 and 0.921 for Paschim Medinipur's lentic and lotic areas, respectively (Figure 8). The R^2 values between body weight and fecundity were measured as 0.640 and 0.786 for Jhargram's lentic and lotic habitats and as 0.679 and 0.755 for Paschim Medinipur's lentic and lotic habitats, respectively (Figure 9). Fecundity was positively linearly correlated with gonad weight and body weight in both the studied habitats. The same result was observed by Hossain et al. (2019) and Paul et al. (2021) for the same species and by Islam and Das (2006), Siddique et al. (2008), Islam et al. (2011), Malla & Banik (2015), Gosavi et al. (2020), and Mawa et al. (2022) for other catfish species. This study has divided gonad maturity into 5 stages for *P. atherinoides*.

Ovary developmental stages (Figure 10):

Immature (Stage 1): Ovaries are thin, colorless, and transparent. Small and filiform, they only occupy one-third of the abdominal space. Oocytes are exceedingly tiny and invisible to the naked eye.

Maturing (Stage 2): Ovaries are pale white/cream in color, with minor granulation discernible to the naked eye. Half of the abdominal cavity is taken up by enlargement signs. Small ova, visible with the naked eye, begin to appear.

Mature (Stage 3): Ovaries are whitish-yellow in color and have a greater anterior expansion than Stage 2. Two-thirds of the abdominal cavity is lobular. The ova have a distinct yolk.

Ripe (Stage 4): Yellowish, voluminous, and with blood vessels; occupies two-thirds of the abdominal cavity, with a loosening of the previously compact arrangement of ova.

Spent (Stage 5): Flaccid, wrinkled, displaying a smaller size than Stage 4; ovaries become drastically smaller in both length and weight and show a sac-like look with a pale white tint.

Testis developmental stages (Figure 11):

Immature (Stage 1): Testis are thin, threadlike, transparent, and white in color, with unorganized tubules.

Maturing (Stage 2): Testis appear slightly longer and slightly more bulbous. The appearance of an indistinct vasa differentia.

Mature (Stage 3): Testis become large and creamy white in color. The Ductus difference is distinct. All spermatogenic cells with the maximum concentration of spermatids are present in seminiferous tubules.

Ripe (Stage 4): Testis are mature and more than two-thirds of the abdominal cavity in size. Spermatozoa-filled seminiferous tubules are easily discharged from the testis with a bit of pressure.

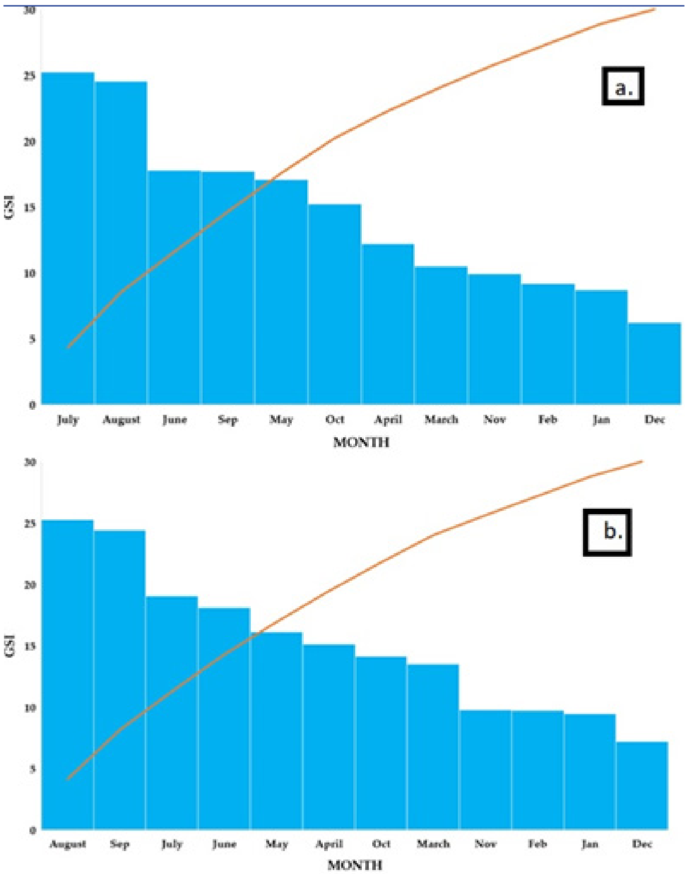

Figure 6. Monthly variation of GSI for *P. atherinoides* in Paschim Medinipur district's: a.) ponds; b.) rivers.

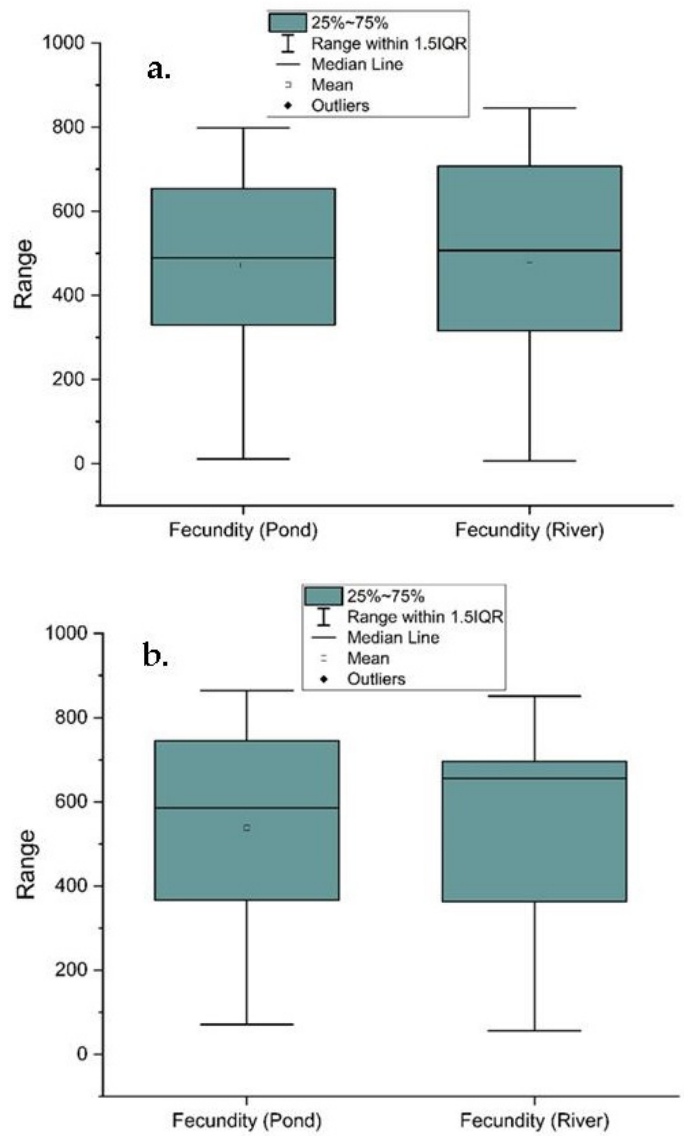

Figure 7. Fecundity of *P. atherinoides* in both habitats of (a) the Jhargram and (b) Paschim Medinipur districts.

Table 2. Total weight, gonad weight, and fecundity of *P. athertenoides* in both habitats of the Jhargram and Paschim Medinipur districts

District	Total Weight(g)				Gonad weight (g)				Fecundity			
	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD
JP	4.44	6.57	5.79	0.659	0.21	2.12	1.264	0.50	65.0	798	482.7	203.02
JR	4.31	6.85	5.90	0.748	0.15	2.41	1.250	0.57	65.0	845	492.6	236.91
MP	4.23	6.77	5.93	0.712	0.15	2.30	1.311	0.56	56.0	851	526.9	243.32
MR	4.36	6.83	5.97	0.738	0.15	2.30	1.319	0.56	71.0	864	538.3	245.12

N = 104; JP = Jhargram Pond; JR = Jhargram River; MP = Paschim Medinipur Pond; MR = Paschim Medinipur River

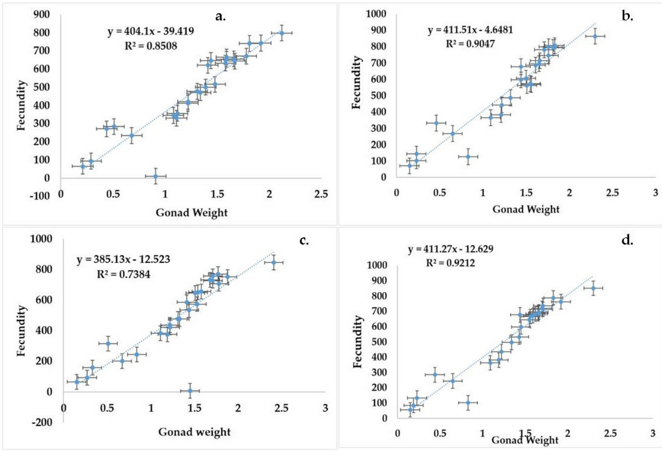

Figure 8. Relationship between fecundity and gonad weight for *P. atherinoides* in theJhargram (a &b) and Paschim Medinipur (c & d) districts; a and c are ponds; b and d are rivers.

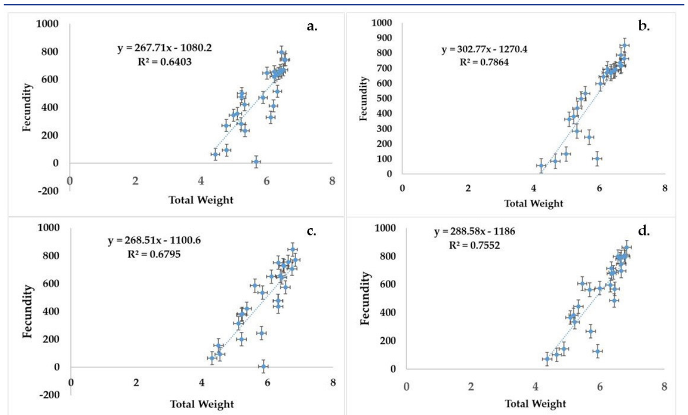

Figure 9. Relationship between fecundity and total weight for *P. atherinoides* in Jhargram (a & b) and Paschim Medinipur (c & d) districts; a and c are ponds; b and d are rivers

Spent (Stage 5): Flaccid gonads fill over half of the abdominal cavity in the spent (Stage 5) condition. Regression of the testis occurs. The cells seem to merge. High amount of primary and secondary spermatocytes.

During the study of ovary development in the lentic habitats (ponds), Stage 1 was noticed from November-March, with a peak in December and a minimum in May. Stage 2 was noticed from November-June, with a peak in April and a minimum in November. Stage 3 was noticed from March-September, with a peak in June and a minimum in September. Stage 4 was noticed from April-September, with a peak in July and a minimum in April. Stage 5 was noticed from June to November, with a peak in October and minimum in June. In the lotic habitats (rivers), Stage 2 of ovary development was noticed from November-July, with a peak in March and a minimum in July. Stage 4 was noticed from April-September, with a peak in July and a minimum in April. Stages 1, 3, and 5 were observed to have the same periods as those in lentic habitats (Figure 12).

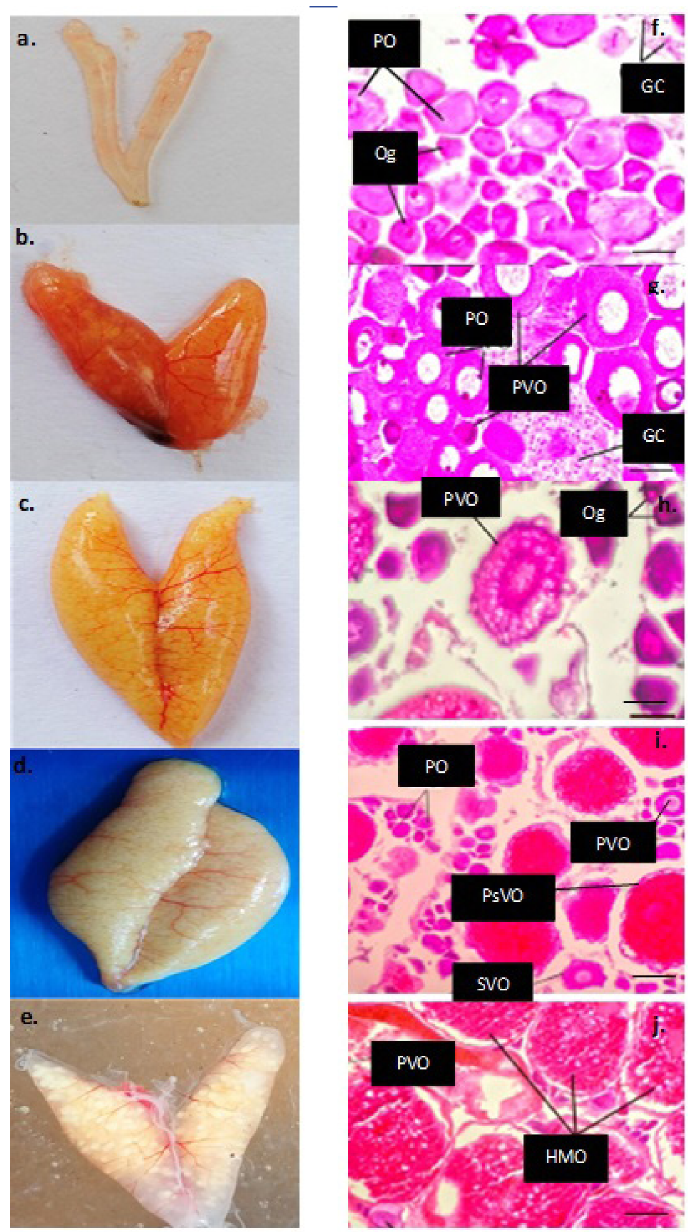

Figure 10. External (a-e) and microscopic (f-j) ovary of *P. atherinoides*. Stage 1 (a & f); Stage 2 (b & g); Stage 3 (c & h); Stage 4 (d & i); Stage 5 (e & j). GC = germ cells, Og = oogonia, PO = primary oocyte, PVO = primary vitellogenic oocyte, PsVO = post-vitellogenic oocyte, SVO = secondary vitellogenic oocyte, HMO = hydrated mature oocyte. Scale bar is at 100 μm.

For the study of testis development in the lentic habitats, Stage 1 was noticed from November-May, with a peak in December and a minimum in May. Stage 2 was noticed from November-June, with a peak in April and a minimum in November. Stage 3 was noticed from February-December, with a peak in June and a minimum in December. Stage 4 was noticed from April-October, with its peak in July and minimum in April. Stage 5 was noticed from June-October, with a peak in October and minimum in June. For the lotic habitats (rivers), Stage 1 of testis

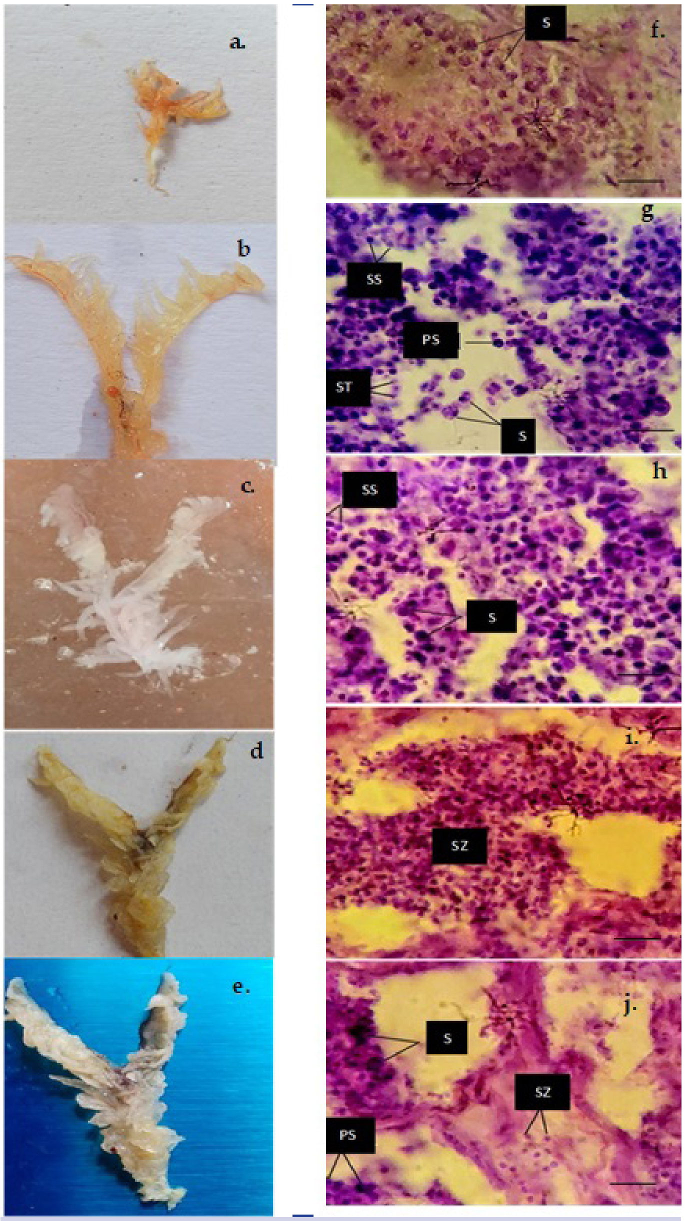

Figure 11. External (a-e) and microscopic (f-j) testes of P. atherinoides. Stage 1 (a & f); Stage 2 (b & g); Stage 3 (c & h); Stage 4 (d & i); Stage 5 (e & j). S = spermatogonia, PS = primary spermatocytes, SS = secondary spermatocytes, ST = spermatids, SZ = spermatozoa. Scale bar is at 100 µm.

development was noticed from November-May, with a peak in January and a minimum in May. Stage 2 was noticed from November-July, with the high in April and low in July. Stage 3 was noticed from February-December, with a peak in June and a minimum in February. Stage 4 was noticed from March-October, with the high in August and low in March. Stages 1, 3, and 5 were also observed to be similar to those in the pond habitats (Figure 13). The results for GSI, gonad development, and fecundity depict *P. atherinoides* to breed once a year between June-September.

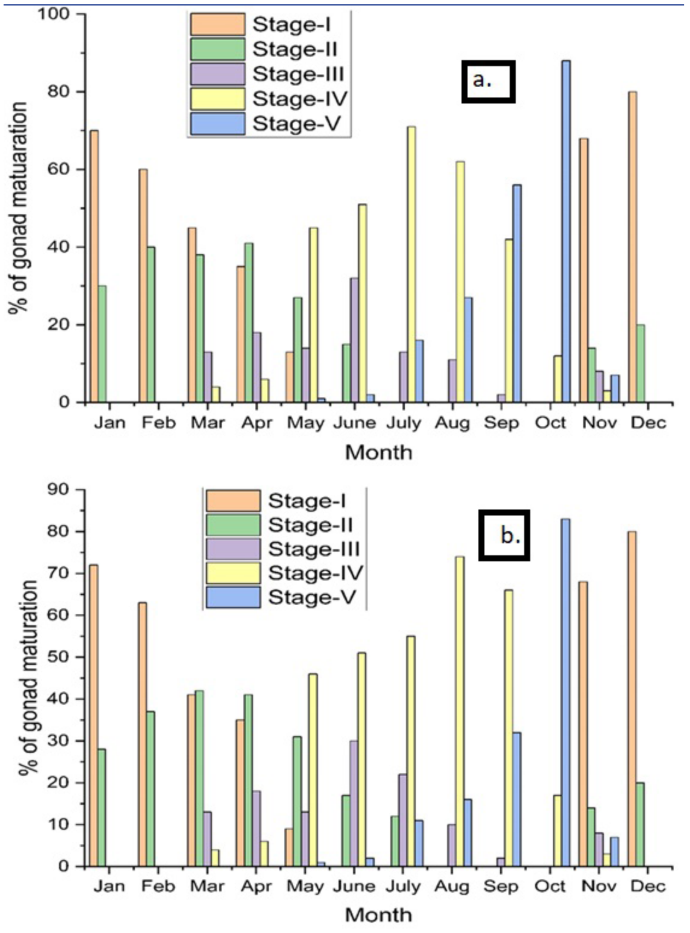

Figure 12. Monthly ovary maturation stages of *P. atherinoides* in both districts: a.) ponds; b.) rivers.

CONCLUSION

The breeding season of *P. atherinoides* has been determined in the study area to occur between June-September. Hence, the study suggests that government fishery managers take certain restrictions when capturing this species during their peak breeding season between June-September. The study's findings can be valuable tools for developing management and protection strategies for conservation and captive propagation. The knowledge from the current study may be applied for better managing *P. atherinoides* in India and for future conservation strategies, as well as for adopting this species as a possible candidate for commercial aquaculture.

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Conflict of Interest: The authors declare no conflicts of interest.

Ethics Committee Approval: Ethical approval was obtained from IAEC (Approval no. 18/IAEC (05)/RNLKWC/2019; dated: July 27, 2019).

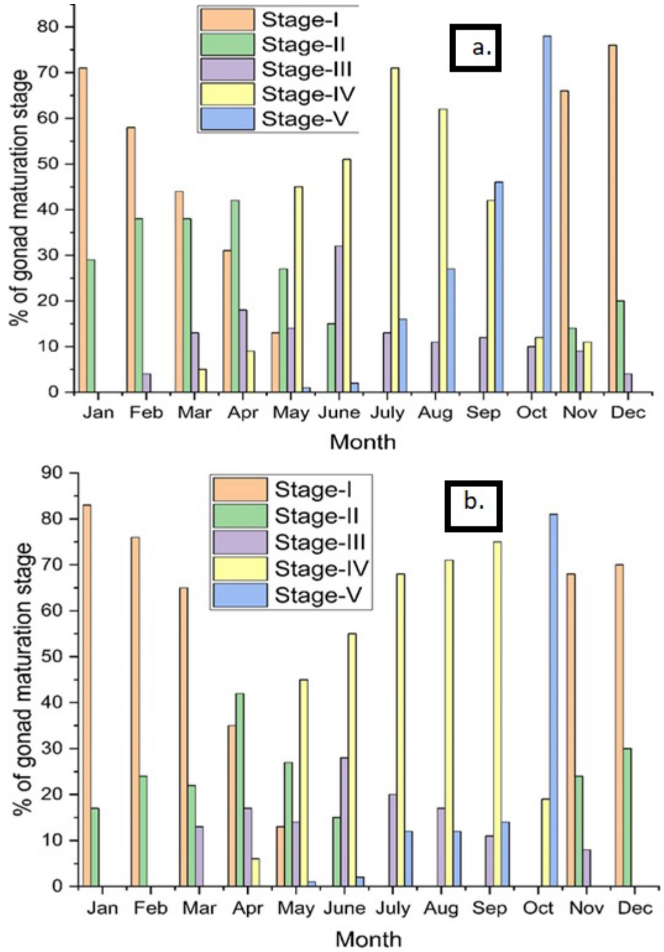

Figure 13.Monthly testis maturation stages of *P. atherinoides* in both districts; a.) ponds; b.) rivers.

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