J. Indian Soc. Coastal Agric. Res. 41(2): 108-119 (2023) https://doi.org/10.54894/JISCAR.41.2.2023.145553

Seasonal Variation in the Biological Traits of Invasive Amazon Sailfin Catfish (*Pterygoplichthys pardalis*) in East Kolkata Wetlands, India

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Received: 22.11.2023 Accepted: 29.12.2023

Invading sailfin catfish *Pterygoplichthys* spp. in East Kolkata Wetlands (EKW), India were studied for their length-weight relationship (LWR), condition factor and reproductive characteristics covering pre-monsoon, monsoon and post-monsoon seasons. Using seine nets, fish samples were taken every month from May to December 2022 from five distinct EKW sites. Season-specific b-values for the LWR showed negative allometric growth, ranging from 2.663 to 2.809. Seasonal variation was negligible for Fulton's condition factor (K_c), which varied between 0.741 and 0.756. The mean relative condition factor (Kn) was likewise found to be near 1 in all seasons (0.999 - 1.041). The sex ratio (male to female) showed an average mean value of 1: 3.61, with no noticeable seasonal change. However, gonado-somatic index (GSI) of males (0.164 ± 0.007) and females (7.174 ± 0.225) during the monsoon months (July - September) was found to be considerably greater (p<0.001) than pre-monsoon and post-monsoon GSI of the respective gender. Females were observed to have a lower mean total length at maturity (31.6 - 35.3 cm) than males (36.2 - 37.1 cm). No significant difference in mean absolute fecundity (3914.63 ± 103.70 nos. female^{-1}) of ripe females was observed, although gonad mass and relative fecundity (RF) differed considerably (p<0.05) by season. Seasonal interactions with study sites were found to have a considerable impact on ripe females' RF and egg size, as well as K_n and GSI of both sexes. It was also noted that the condition factors and reproductive characteristics of sailfin catfish varied each month. Overall, mean K_n values of close to 1 (~1) indicate that sailfin catfishes in EKW are in excellent condition of health and well-being. Additionally, the mean GSI of mature females was found continuously greater than three (>3) in each month of the study period, indicating that these fishes in EKW had a protracted breeding time.

(***Key words:*** *Alien fishes, Condition factor, Length-weight relationship, Reproduction*)

The rise of international trade in the pet and food industries has resulted in the introduction of numerous fish species, with biological invasions being an unintended consequence of such actions (Gozlan *et al.,* 2010; Sundaray *et al.,* 2022). Members of the family Loricariidae, which are native to South America, especially those in the genus *Pterygoplichthys* (known as the South American sailfin catfish or sailfin armoured catfish) have been introduced to several tropical and sub-tropical regions worldwide as aquarium pets (Orfinger and Goodding, 2018). Consequently, as a result of their escape from fish-rearing facilities or release by pet fish owners, a number of *Pterygoplichthys* species have become invasive into the freshwater systems of warm-watered regions around the world (Hussan *et al.,* 2019; Rueda-Jasso *et al.,* 2013; Wanasinghe *et al.,* 2023; Wei *et al.,* 2017). The natural habitats of these fishes (seasonally flooded Amazonian woods) forced them to evolve with a range of survival-enhancing traits, including the ability to breathe air in low-oxygen environments, be a capable nest-guarder with a relatively high fecundity, have large stores of coelomic fat, and withstand prolonged desiccation in burrows (Gibbs *et al.,* 2008; Hoover *et al.,* 2004), which may have played a major role in the

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global invasion success of these fishes (Orfinger and Goodding, 2018).

Sailfin catfishes were brought into India as ornamental fish and over time these fishes have been introduced and become invasive in many natural water bodies as well as large aquaculture systems of different parts of India including East Kolkata Wetlands (EKW), West Bengal (Hussan *et al.,* 2016; Hussan *et al.,* 2019). Although there have been reports of these fishes having a serious negative influence on biodiversity (Escalera-Vázquez *et al.,* 2019) and aquaculture of EKW (Hussan, 2016; Hussan *et al.,* 2019), very little is known about their development and reproductive patterns in response to the seasonal variations in local conditions. However, there have been reports of differences in the growth, maturity, and reproductive behaviour of loricariids between their native range and the areas they have invaded (Gibbs *et al.,* 2017). For instance, compared to their native range in Central and South America, non-native suckermouth catfish (*Hypostomus* spp.) in the invaded San Marcos River, Texas (North America) have a less distinct season of peak reproductive activity and a more seasonally compressed period of reproductive quiescence (Cook-Hildreth *et al.,* 2016). *Pterygoplichthys disjunctivus* has modified its reproductive tactics (expanded its reproductive season with increased fecundity and gonado-somatic index) in the invaded Volusia Blue Spring, North America in response to the pressures of the novel environment (Gibbs *et al.,* 2017).

Therefore, the goal of the present study was to elucidate the growth and reproductive behaviour of *Pterygoplichthys* species in EKW and ascertain whether any seasonal patterns were present. Mainly due to four closely related species (as *P. pardalis, P. disjunctivus, P. anisitsi* and *P. multiradiatus*) that are distinguished primarily by the characteristics of their abdominal spots and patterns (Armbruster and Page, 2006; Page and Robins, 2006), species delineation within the genus *Pterygoplichthysis* little fuzzy (Vargas-Rivas *et al.,* 2023; Wu *et al.,* 2011). Yet largely based on these characteristics only, the majority of the invading *Pterygoplichthys* populations in India, including those from EKW, were identified as *P. pardalis* or *P. disjunctivus* and/or their hybrids (Hussan *et al.,* 2018; Hussan *et al.,* 2019; Muralidharan *et al.,* 2015). However, Sahoo *et al.* (2022) based on mtDNA COI gene sequence analysis and BOLD data matching confirmed, all the specimens of *Pterygoplichthys* having widely variable abdominal spots and patterns from East Kolkata Wetlands, West Bengal, India as *Pterygoplicthys pardalis*. Hence, we referred all the specimens used in this study as *Pterygoplichthys pardalis*, commonly known as Amazon sailfin catfish (hereafter as 'sailfin catfish')

MATERIALS AND METHODS

Sampling sites and acquisition of samples

This research was carried out at East Kolkata Wetlands (EKW, 22°25′ - 22°40′ N; 88°20′ - 88°35′ E), a designated 'International Ramsar Site' and the 'World's Largest Integrated Wastewater Fisheries', which lies on the eastern outskirt of the city of Kolkata in India. Through a network of locally excavated secondary and tertiary canals, over 260 shallow fish ponds in the EKW receive over 900 MLD (million litres per day) nutrient-rich effluent (pre-settled sewage) from the Kolkata Metropolitan region, which is utilized to produce 20,000 MT of fish, 50,000 MT of vegetables, and irrigate 4700 ha of paddy lands (EKWMA and WISA, 2021). Sailfin catfishes (*Pterygoplichthys* spp.) were first reported from the pisciculture bheries (a local term of fishery pond) of these wetlands in 2009 and within a decade these fishes have invaded extensively in EKW water bodies, likely supported by the nutrient-rich environment, ample food in the form of detritus and a congenial environment for shelter and breeding in the form of water hyacinth cover (Hussan *et al.,* 2019).

Five distinct sites of EKW were selected for sampling based on the quantity of sewage received for fish rearing and presence of *Pterygoplichthys* spp.in the bheries: Narkeltala bhery, B1, 22°33′32″ N, 88°26′55″ E; Chacker bhery, B2, 22°33′11″ N, 88°26′37″ E; Jhagrasirsha bhery, B3, 22°32′39″ N, 88°27′31″ E; Chacharia Fishermen Cooperative Society Ltd./ Chachariabhery, K1, 22°31′31″ N, 88°28′41″ E; and Nalban-1 Matsyajibi Samabay Samiti Ltd./ Nalban-1 bhery, K2, 22°30′39″ N, 88°28′36″ E (Fig. 1). The study lasted for eight months from May 2022 to December 2022, covering roughly pre-monsoon (May - June), monsoon (July - September) and post-monsoon (October - December) seasons.

Using seine nets, 20 - 40 fish samples were taken

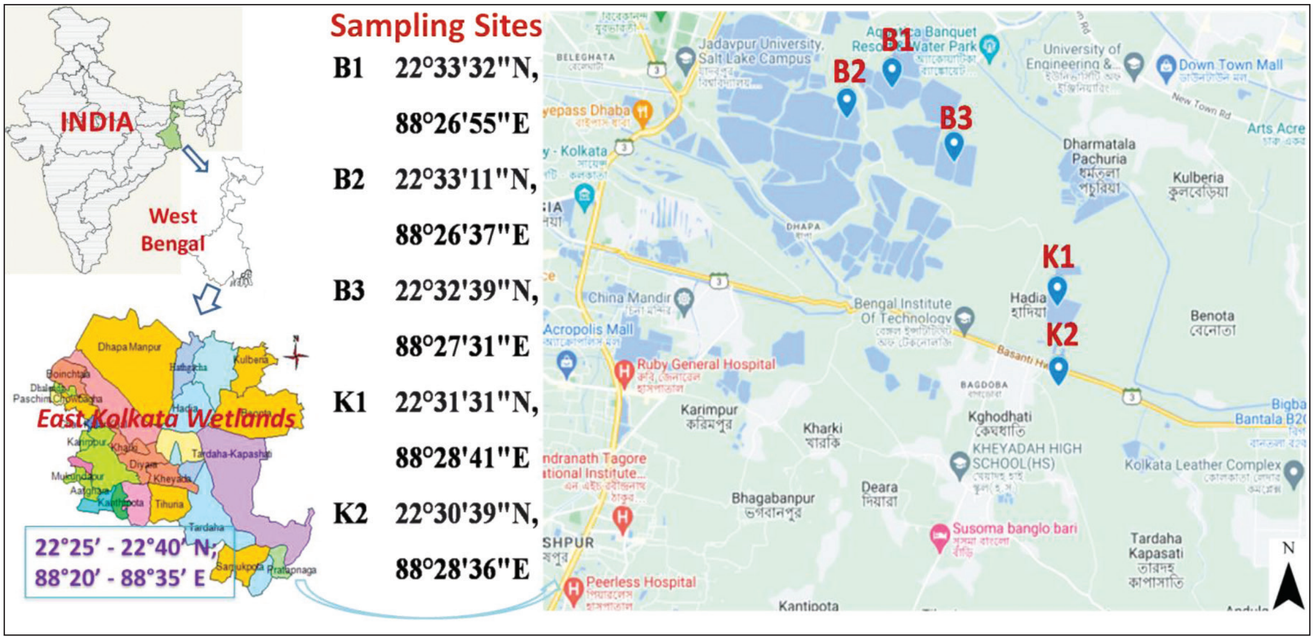

Fig. 1. Location map of East Kolkata Wetlands (EKW) and sampling sites

from each sampling site every month. The length of each fish was measured and recorded in cm (nearest 1 mm) as total length (TL) and standard length (SL). The whole-body weight (W) was measured to the nearest gram (0.1 g). All adult fish in the sample (individuals with W>100 g) were then anesthetized and dissected to examine the gonads to determine their gender and maturity status. Based on macroscopic examination, individuals with gonads (hereafter 'sexually mature'; includes both individuals with eggs or milt and individuals with quiescent gonads) were classified as male or female, following Gibbs *et al.* (2008) and Jumawan and Herrera (2014). Males were considered "ripe" when milt was found in the gonad, whereas females were considered "ripe" when the ovary occupied more than half of the body cavity, was orange in colour, had a thin ovarian wall, high vascularization, and contained large yellow oocytes (after Gibbs *et al.*, 2008; Jumawan and Herrera, 2014). Male and female gonads were then carefully removed, and the weights of the gonads (GM) were measured nearest to 0.01 g using an electronic balance. Only ripe females were used for studying the fecundity and egg size. To estimate absolute fecundity (AF) small sub-samples from the front, middle, and posterior regions of the left lobe ovary of the female were taken, weighed, and the eggs in the sub-samples were counted, averaged, and extrapolated to the egg count of the total ovary (Samat *et al.,* 2016). In order to calculate the egg size, 100 eggs were chosen at random and their diameter (nearest 0.01 mm) was measured with a vernier calliper (Bombay Tools Center Bombay Pvt Ltd.; ± 0.01 mm accuracy).

Estimation of biological traits

The power equation $W = aTL^b$, where W is the total weight (in g), TL is the total length (in cm), 'a' is the intercept, and 'b' is the slope, was used to determine the relationship between the fish's weight and its total length (LWRs). Fulton's condition factor (K_c) was calculated using the formula $K_c = 100 \times W/TL^3$. The relative condition factor (K_n) was computed as $K_n = W_o/W_c$, where, W_o and W_c represent the observed and calculated total weight of a fish, respectively (Le Cren, 1951). Wc was calculated as $W_c = aTL^b$. We calculated the gonado-somatic index (GSI) using the formula GSI= (Gonad weight/Total body weight) x 100. The number of mature ova in the ovary was counted for each ripe female fish as a proxy for absolute fecundity (AF). Relative fecundity (RF) was calculated as RF = Absolute fecundity/Total body weight. The calculated mean TL at maturity (TL_m) was determined from the percentage of mature males and females in each one-centimetre size class, following the Trippel and Harvey (1987) method.

Statistical analysis

IBM SPSS statistical software version 23.0 (SPSS Inc., Chicago, IL, USA) was used to analyze all of the data. Mean and standard error or mean and standard deviation (mean ± SE or mean ± SD) were used to express all numerical data in tables and graphs, respectively. The anticipated values for isometric growth (b=3) and the b values achieved for each season were compared using a t-test to analyze statistically significant differences. An isometric growth is attributed when b is not statistically different from 3 (p>0.05). On the other hand, when b differs from 3 significantly (p<0.05) it implies either a positive or negative allometric growth Growth pattern was identified as positive allometric growth when b >3 and negative allometric when b <3 (Yilmaz *et al.,* 2012). One-way ANOVA was used to test the variation in life-history traits of sailfin catfish between seasons or months. Whenever ANOVA analysis showed significant differences, paired differences were verified through Tukey's post-hoc test. Further, the two-way ANOVA analysis was performed to verify if there were any interaction effects of study sites and seasons (site x season) on the life-history traits of sailfin catfish. All tests were set at p< 0.05.

RESULTS AND DISCUSSION

Growth allometries, length-weight relationships and condition factor

During the study period, 1107 sailfin catfish individuals were collected from the five sampling sites. Total length and weight varied from 8.40 to 49.50 cm (mean ± SE = 32.24 ± 0.25 cm) and 3.0 to 916 g (mean ± SE = 268.81 ± 5.34 g), respectively (Table 1). Sailfin catfish specimens from all study sites polled together showed no discernible variation in length or weight between seasons (TL: $F_{2,1104}$ = 1.553, p = 0.216; W: $F_{2,1104}$ = 2.280, p = 0.103; one-way ANOVA). The b-values for the TL and W relationship (Table 1) varied a little by season and ranged from 2.658 to 2.809. These b-values were found to be significantly lower (p≤0.001, Student's t-test) than the predicted values for isometric growth (b=3), suggesting that these fishes have a tendency tobecome thinner as they get bigger (negative allometric growth). However, the obtained b-values in this study are within the predicted range of 2.5<b <3.5 (Froese, 2006) and consistent with the findings of Samat *et al.* (2008) and Rueda-Jasso *et al.* (2013) for *Pterygoplichthys* species. Furthermore, the values of correlation coefficients (r^2) of LWRs were found in the range of 0.9 to 1.0, indicating a strong correlation between total length and weight, and almost ideal growth of these fishes in EKW.

The values of K_c and K_n showed significant variations (K_c: $F_{2,1104}$ = 5.670, p = 0.004; K_n: $F_{2,1104}$ = 8.769, p<0.001, one-way ANOVA) between the seasons (Fig. 2). Monsoon and post-monsoon season CFs were found to be minimally greater than the pre-monsoon CFs, suggesting that seasonal fluctuations may have little impact on the overall health of these catfishes (Rueda-Jasso *et al.,* 2013; Samat *et al.,* 2008). The slightly higher K_c and K_n values observed during the monsoon and post-monsoon seasons may have resulted from the vast number of fish reaching full maturity at that time (Samat *et al.,* 2008). According to Le Cren (1951), a notable departure of K_n values from 1 signifies variations in the accessibility of food and the impact of physical and chemical attributes on the life cycles of fish species. Thus, slightly lower K_n values in the fish group during the pre-monsoon season (0.999 ± 0.007 SE) may be associated with reduced food availability and/or less favourable environmental variables for optimal growth (De Giosa *et al.,* 2014; Dinh *et al.,* 2022; Jisr *et al.,* 2018) during that period. However, upon combining all specimens of sailfin catfish collected during the present study, the K_n values were found to be greater than 1 (1.019 ± 0.004 SE), indicating that there was enough food in EKW for the fishes to reach their maximum growth potential (Dinh *et al.,* 2022; Jisr *et al.,* 2018). It also supports the opinion that sailfin catfishes can sustain their fitness even in challenging circumstances due to the plasticity of their phenotypic traits (Wei *et al.,* 2022).

TLs, Ws, and the LWRs parameters (a, b, and r^2) also varied on a monthly basis, in both the study locations. However, exponent 'b' values were found to be well within the expected range of 2.5<b<3.5 (Froese, 2006), except for the months of August (b = 2.258) and December (b = 2.471) at location K. Variation in CFs of sailfin catfish with month were also observed in both the study locations (Fig. 3).

Morphometrics and gonado-somatic index of mature male and female

In the present study, sex ratios of sailfin catfishes

Table 1. *Variations total length (TL), whole body weight (W), calculated parameters of the length-weight relationships (a: intercept and b: slope of the equa tion, r^2: coefficient of determination) and growth behaviour of Pterygoplichthys species by season. A: negative allometry, SE: Standard Error.*

Season	No. of fish	TL (cm)		W (g)		Length-weight parameters			Deviation from b=3 (p-value)	Growth behaviour
		Range	Mean ± SE	Range	Mean ± SE	a	b	r^2		
Pre-monsoon	281	12.80 - 49.20	32.07 ± 0.38[a]	14.20 - 795.5	263.73 ± 8.11[a]	0.023	2.663	0.936	0.000	- A
Monsoon	425	8.40 - 49.50	31.58 ± 0.32[a]	3.0 - 916	255.73 ± 6.73[a]	0.024	2.658	0.952	0.000	- A
Post-monsoon	401	10.20 - 48.60	32.42 ± 0.38[a]	4.30 - 885	277.45 ± 8.11[a]	0.013	2.809	0.952	0.001	- A
Total	1107	8.40 - 49.50	32.24 ± 0.25	3 - 916	268.81 ± 5.34	0.017	2.746	0.951	0.000	- A

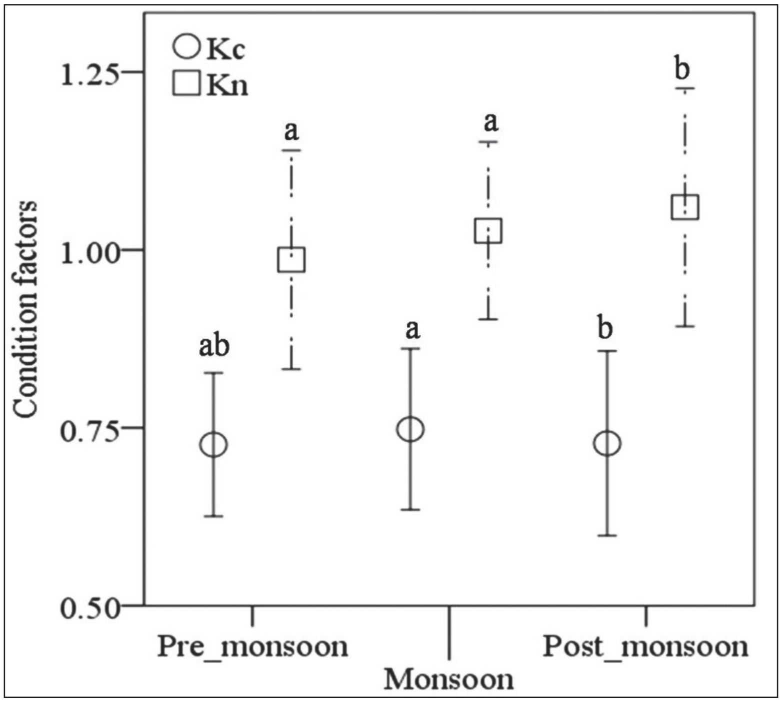

Fig. 2. *Season-wise variation in Fulton's condition factor (K_c) and relative condition factor (K_n) of sailfin catfish in East Kolkata Wetlands. Bars having different alphabetical superscripts are significantly different (p<0.05; one-way ANOVA followed by post hoc Tukey test). Values are expressed as mean ± standard deviation.*

were found to be strongly female-biased (Table 2), with no discernible seasonal variation ($\chi^2 = 1.368$, df = 4, $p = 0.850$). The populations of *Pterygoplichthys* fishes in the majority of the Guangdong Province, China (Wei *et al.,* 2017), as well as the Langat River in the Malaysian Peninsula (Samat *et al.,* 2016), have also been documented to have female-biased sex ratios. Seasonal variations were also found insignificant statistically for the length ($F_{2,104} = 1.840$, $p = 0.164$) and weight ($F_{2,104} = 1.588$, $p = 0.209$) of males as well as for the length of females ($F_{2,324} = 2.692$, $p = 0.069$; one-way ANOVA). However, the weight of mature females was found to be considerably higher ($p = 0.025$, Tukey's post-hoc test) in the post-monsoon season than in the pre-monsoon season (Table 3). Seasonal variations were also observed in the mean GSI of both males ($F_{2,104} = 29.833$, p<0.001) and females ($F_{2,324} = 28.951$, p<0.001). In comparison to the pre-monsoon and post-monsoon GSI of the respective gender, the GSI of both males (0.164 ± 0.007 SE) and females (7.174 ± 0.225 SE) during the monsoon months (July – September) were found to be higher significantly (p<0.001).

Similar to our observation, seasonal variation in GSI of male and female *Pterygoplichthys* species was also noted by Gibbs *et al.* (2008), Jumawan *et al.* (2016) and Wanasinghe *et al.* (2023). At Volusia Blue Springs, Florida, and Marikina River, Philippines, respectively, Gibbs *et al.* (2008) and Jumawan *et al.* (2016) observed elevated GSI values of female *P. disjunctivus* at the beginning of May - June, with a peak in July and fall from September. Further, male sailfin catfish's (*P. disjunctivus*) mean monthly GSI was found to be significantly higher in the months of May through October and significantly lower in the months of November through April by Wanasinghe *et al.* (2023). Despite the fact that female GSI varied significantly by season during the present study, the mean GSI of mature females was found to be constantly above three (>3) in all months, indicating the availability of ripe females throughout the study period (May - December). Almost alike, Wanasinghe *et al.* (2023) reported year-round availability of mature male and female *P. disjunctivus* in Polgolla Reservoir, Sri Lanka.

The mean size of sailfin catfish at first maturity

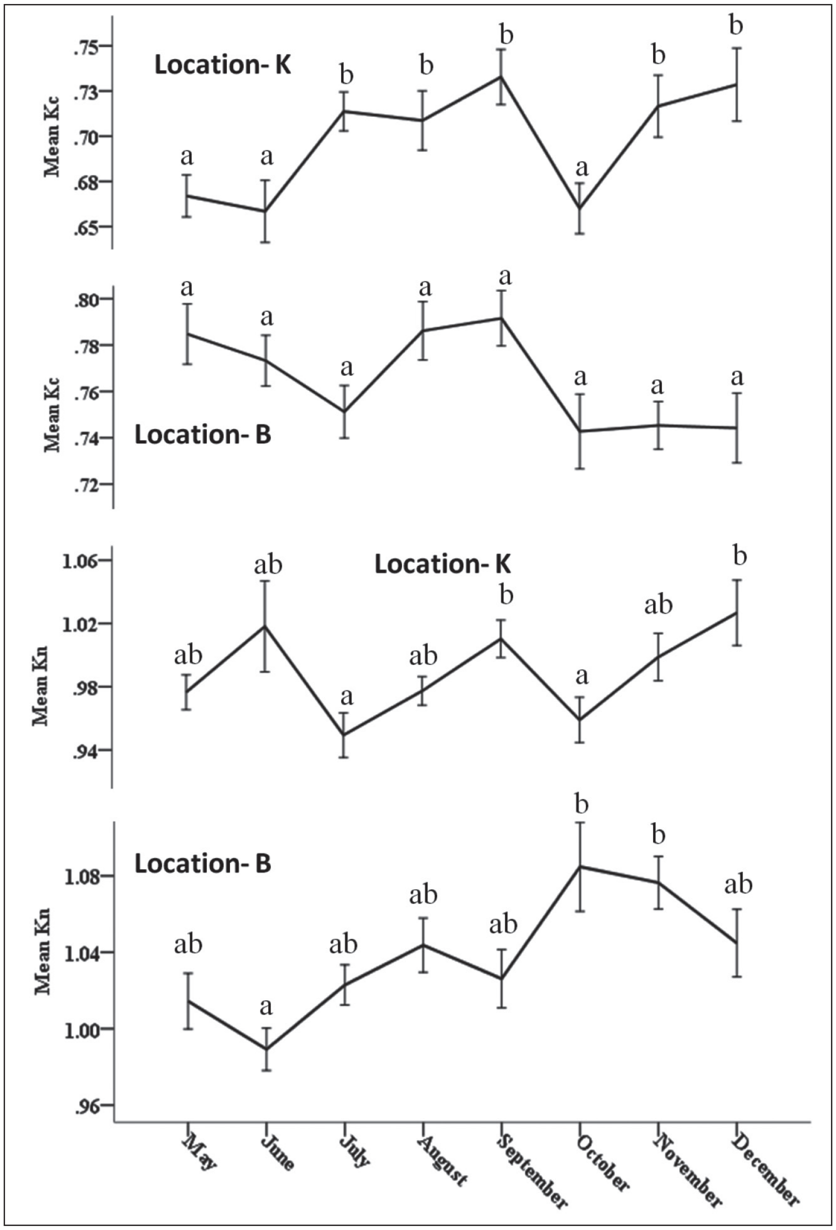

Fig. 3. *Location-wise monthly variation in Fulton's condition factor (K_c) and relative condition factor (K_n) of sailfin catfish. Bars having different alphabetical superscripts are significantly different ($p<0.05$; one-way ANOVA followed by Tukey's post-hoc test). Values are expressed as mean ± standard error.*

Table 2. *Total number of Pterygoplichthysspecimens dissected (N), sex ratio (male to female), number of sexually mature males (M_m) and females (F_m) at different stages of maturity (Mat) with indication of the number of ripe individuals (R) by season.*

Season	N	Sex ratio	Male (M_m)		Female (F_m)	
			Mat	R	Mat	R
Pre-monsoon	139	1: 3.21	19	8	61	23
Monsoon	217	1: 2.84	45	27	128	76
Post-monsoon	252	1: 3.21	43	17	138	64
Total	608	1: 3.05	107	52	327	162

was calculated (TL_m) as 31.60 to 35.30 cm TL (24.70 - 27.30 cm SL) for females and from 36.20 to 37.10 cm TL (27.90 - 28.60 cm SL) for males, which are higher than the mean size of *Pterygoplichthys* species at first maturity reported by Wei *et al.* (2017). They reported that *Pterygoplichthys* species were maturing at a significantly lesser size in Guangdong Province, China, compared to their other non-native ranges, with mean size at first maturity for females from 150 to 223 mm SL, while for males it was between 160 and 249 mm SL. Though it is not clear why sailfin catfishes are maturing at a greater size in EKW, according to Gibbs *et al.* (2017) the areas where a species is reaching maturity at a greater size might be investing more energy for environmental adaptation rather than for reproduction. Inbreeding among a small group of isolated individuals in a specific place (the "founder effect") has also been linked to this type of variation (Matute, 2013).

Reproductive traits of ripe females

The mean length, weight and other reproductive traits of 162 ripe female sailfin catfish are presented in Table 4. In the study, no significant difference in length and weight of ripe females by season was observed ($p>0.05$; one-way ANOVA). However, gonad mass (GM) and GSI of ripe females (GSI-FR) varied significantly by season ($p<0.05$; one-way ANOVA). The highest recorded GM (32.74 ± 1.54 g) and GSI-FR (7.90 ± 0.27 SE) in the monsoon season, were found substantially greater only from the pre-monsoon season ($p<0.05$, Tukey's post-hoc test). This suggests that sailfin catfishes in EKW might have increased breeding capacity from the month of July, with the beginning of overflowing monsoon in Kolkata. Wanasinghe *et al.* (2023) found that although *P. disjunctivus* in Polgolla Reservoir is capable of reproducing all year round, the species has a higher breeding capacity during specific times of the year that coincide and correlate with the rainy season. Seasons did not significantly affect the AF of ripe females in EKW ($F_{2,159} = 1.623$, $p = 0.201$; one-way ANOVA). The AF of ripe female fish in the present study varied from 2100 to 7850, which is comparatively less than the AF of *P. pardalis* reported by Samat *et al.* (2016) in the Langat River of Peninsular Malaysia, found to be between 1297 and 18791. However, RF by season was found significantly different ($F_{2,159} = 5.233$, $p<0.001$; oneway ANOVA). Pre-monsoon RF was found to be considerably lower ($p<0.05$) in comparison to the monsoon and post-monsoon RF. The highest relative fecundity (> 10 eggs per g body weight of female) was recorded in the months of July, August and October during the study. *P. disjunctivus* from Adolfo López Mateos El Infiernillo Reservoir, Mexico, had the maximum RF (12.6 ± 2.02 eggs) in August and September, and average RF for the months with the highest reproductive activity (July to September) was 9.81 ± 3.07 (Rueda-Jasso *et al.,* 2013). Gibbs *et al.,* (2017) have also shown sailfin catfish (*P. disjunctivus*) to have significantly higher relative fecundity during the breeding season compared to the non-breeding season in Volusia Blue Spring, Florida. The overall ova diameter of ripe female varied between 1.6 and 3.1 mm, which was consistent with the reported maximum ova diameters of 3.3 mm for *P. pardalis* (Samat *et al.,* 2016) and 3.6 mm for *P. disjunctivus* (Gibbs *et al.,* 2008).

Interaction effect of season with study sites on biological traits of sailfin catfish

The interaction effects of seasons and study sites (Table 5) on TL and W were determined to be insignificant (TL: $F_{8,1092} = 0.860$, p = 0.550; W: $F_{8,1092} = 0.682$, p = 0.708; two-way ANOVA; Table 5). However, their interaction effects on relative condition factor (K_n) was found to be highly significant ($F_{8,1092} = 6.030$, $p<0.001$; two-way ANOVA). The interaction between the season and study site also found to have a highly significant influence on GSI, RF and egg size of mature individuals (all $p<0.05$). This finding implies that habitat conditions and environmental factors have an impact on fish growth patterns (Wei *et al.,* 2022). However, we didn't found any specific studies in the same line to compare, though Gibbs *et al.* (2017) reported varying patterns of effect of study year, season, and month and their interaction on reproduction of *P. disjunctivus* at Volusia Blue Spring, Florida. They observed that, although seasons and years had a considerable impact on female GSI and relative fecundity (all $p<0.001$), their (years x season) interaction effect on both the parameters was insignificant (p = 0.72 - 0.75). On the other hand, they found effect of years, month, as well as their interaction on female GSI and male GSI were highly significant (all $p<0.05$).

The length-weight relationship and condition factors of sailfin catfish in East Kolkata Wetlands showed no noticeable seasonal change during the period of present

Table 3. *Mean (± SE) total length (TL), weight (W) and gonado-somatic index (GSI) of sexually mature specimens (by sex); and their calculated mean TL at maturity (TL_m) by season. SE: Standard Error*

Season	Mean TL (cm)		Mean W (g)		Mean GSI		TLm(cm)	
	Male (M)	Female (F)	Male (M)	Female (F)	Male (M)	Female (F)	M	F
Pre-monsoon	35.66 ± 0.76^{a}	36.31 ± 0.48^{a}	319.68 ± 19.14^{a}	330.35 ± 14.59^{a}	0.083 ± 0.012^{a}	5.44 ± 0.34^{a}	36.8	35.3
Monsoon	37.39 ± 0.46^{a}	34.96 ± 0.62^{a}	358.84 ± 12.71^{a}	351.62 ± 12.03^{ab}	0.164 ± 0.007^{b}	7.17 ± 0.22^{b}	36.2	31.6
Post-monsoon	36.98 ± 0.53^{a}	37.36 ± 0.48^{a}	352.45 ± 11.72^{a}	389.07 ± 14.02^{b}	0.108 ± 0.005^{a}	5.96 ± 0.21^{a}	37.1	33.1
Total	36.92 ± 0.32	36.32 ± 0.31	349.26 ± 7.92	363.59 ± 8.11	0.126 ± 0.005	6.15 ± 0.15	37.4	33.9

Means in a column with different superscripts indicate significant differences at $p<0.05$ (one-way ANOVA followed by Tukey's post-hoc test)

Table 4. *Variation in average (mean ± SE) length and weight, gonad mass, gonado-somatic index (GSI_R), absolute fecundity (AF_R; in numbers), relative fecundity (RF_R; in numbers per g female body weight) and egg size (in mm) of ripe female fishes by season. SE: Standard Error*

Season	n	Biological traits of ripe female fishes						
		Length (cm)	Weight (g)	Gonad mass (g)	GSI_R	AF_R	RF_R	Egg size
Pre-monsoon	23	36.99 ± 1.25^{a}	378.04 ± 31.23^{a}	23.68 ± 2.03^{a}	6.18 ± 0.52^{a}	3809 ± 215^{a}	8.72 ± 0.48^{a}	2.17 ± 0.063^{a}
Monsoon	76	36.46 ± 0.67^{a}	375.81 ± 19.26^{a}	32.74 ± 1.54^{b}	7.90 ± 0.27^{b}	4113 ± 151^{a}	10.13 ± 0.13^{b}	2.25 ± 0.042^{a}
Post-monsoon	63	37.76 ± 0.77^{a}	396.25 ± 20.46^{a}	$29.64 \pm 1.82a^{b}$	$7.38 \pm 0.32a^{b}$	3717 ± 166^{a}	9.71 ± 0.14^{b}	2.25 ± 0.045^{a}
Total	162	37.04 ± 0.47	384.08 ± 12.77	30.13 ± 1.01	7.55 ± 0.19	3914 ± 103	9.88 ± 0.11	2.23 ± 0.029

Means in a column with different superscripts indicate significant differences at $p<0.05$ (one-way ANOVA followed by Tukey's post-hoc test)

Table 5. *Two-way ANOVA results for the effect of seasons (SN) and study sites (SS) as well as their interaction effect on the biological traits of Pterygoplichthys species. Significant effects are indicated in bold (p<0.05).*

Variables	SS			SN			SS x SN		
	df	F	p	df	F	p	df	F	p
TL_{total}	4	0.845	0.496	2	0.577	0.562	8	0.860	0.550
W_{total}	4	2.587	0.036	2	1.504	0.223	8	0.682	0.708
K_n	4	5.351	<0.001	2	7.180	<0.001	8	6.030	<0.001
TLM_m	4	3.420	0.012	2	1.498	0.229	8	0.512	0.844
WM_m	4	2.071	0.091	2	1.574	0.213	8	0.560	0.808
TLF_m	4	4.350	0.002	2	2.419	0.091	8	1.396	0.197
WF_m	4	0.560	0.692	2	3.741	0.025	8	1.340	0.223
$GSI\text{-}M_m$	4	3.140	0.018	2	23.175	<0.001	8	2.517	0.016
$GSI\text{-}F_m$	4	2.273	0.032	2	33.680	<0.001	8	1.622	0.118
$GSI\text{-}F_R$	4	3.647	0.007	2	4.844	0.009	8	2.264	0.026
GM_R	4	3.286	0.013	2	3.759	0.026	8	1.004	0.435
AF_R	4	0.883	0.476	2	1.497	0.227	8	1.162	0.326
RF_R	4	1.018	0.401	2	16.255	<0.001	8	5.504	<0.001
Egg size	4	0.858	0.491	2	1.038	0.357	8	3.616	0.001

[mean total length (TL_{total}), whole body weight (W_{total}) and relative condition factor (K_n) of all specimens; mean total length of sexually mature male (TLM_m) and female (TLF_m); mean whole body weight of sexually mature male (WMm) and female (WF_m); gonado-somatic index of mature male ($GSI\text{-}M_m$), mature female ($GSI\text{-}F_m$) and ripe female ($GSI\text{-}F_R$); and ripe female's gonad mass (GM_R), absolute fecundity (AF_R), relative fecundity (RF_R) and egg size]

study. Moreover, mean relative condition factor (K_n) was found close to the well-being value of one (~1) in all seasons, indicating that these fishes are adapted very well in the habitats of EKW. Though reproductive traits of mature fishes showed some seasonal variations, availability of mature females with GSI greater than three (>3) in each month of the study period indicate that these fishes in EKW had a protracted breeding time. Therefore, in order to prevent sailfin catfishes from spreading and proliferating in the East Kolkata Wetlands, as one of the options we can recommend that sailfin catfishes be harvested all year long.

ACKNOWLEDGEMENT

The current work is a part of Doctoral research of the first author under the SERB-DST funded project. The funding support of Science and Engineering Research Board (SERB), Government of India (AU/DBLS/SERB-CRG/2018/001909/2019-20/02) to first and corresponding author is gratefully recognized. We are thankful to the Director of ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar and Vice Chancellor, Director of Research and Dean (Fisheries) of Karnataka Veterinary, Animal and Fisheries Sciences University for extending the facilities to carry out the experiments.

CONFLICTS OF INTEREST

The authors state that they have no financial or interpersonal conflicts that might have affected the findings of this study.

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