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First report on biometric parameters and life-history priors of whitespot sandsmelt *Parapercis alboguttata* (Gunther, 1872) from North-eastern Arabian Sea

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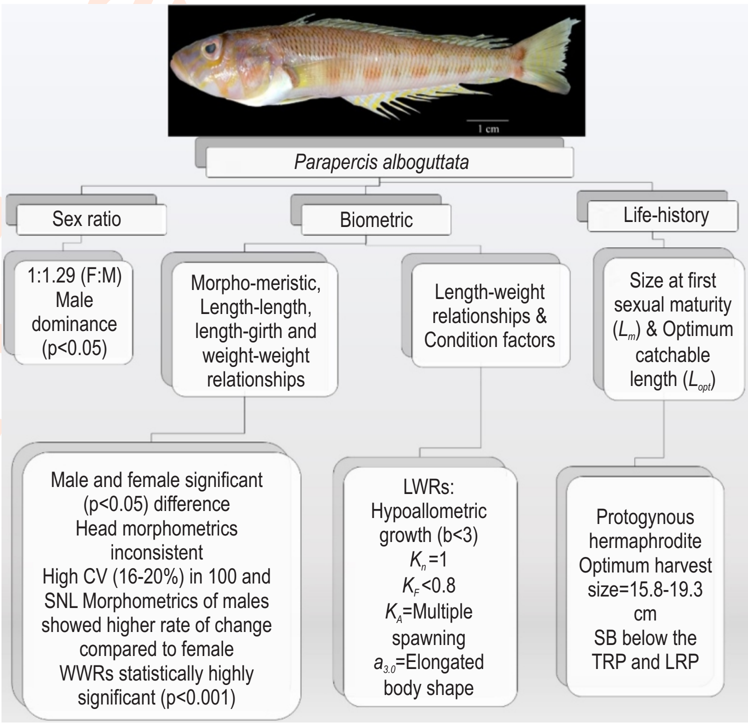
Abstract

Aim: The study aimed to evaluate the sex ratio, biometric characteristics, and life-history traits of *Parapercis alboguttata* along North-eastern Arabian Sea.

Methodology: The statistical analysis of sex ratio, morpho-meristic characteristics, length-weight relationships, condition factors, and life-history features of *P. alboguttata* were examined for one year from September 2022 to August 2023 for both sexes.

Results: The mean sex ratio manifested male dominance (1F:1.29M), which significantly deviated from the 1:1 ratio (χ^2=6.891; *p*<0.05). All the 29 morphometric characteristics subjected to univariate ANOVA showed significant (p<0.001) differences between male and female specimens. Head morphometrics found in the intermediate to environmentally controlled category suggested that these characteristics were inconsistent. Allometric morphometric relationships revealed isometry with TL and allometry with HL for most morphometric parameters. The *b* value of length-weight relationships of combined sexes depicted significant (*p*<0.05) deviation from 3 indicating hypoallometric growth (b<3) with absolute fitness of growth model (r^2>0.982). Mean relative condition factor was found near unity (≈1) in different month and size groups. Corporeal status based on allometric condition factor proclaimed that the species spawn twice a year from October to December and April to August. Sex ratio in different size groups and size at first sexual maturity (L_m) revealed that *P. alboguttata* is a protogynous hermaphrodite.



Interpretation: The current findings proclaimed that the stock is likely to be overfished due to large removal of mega-spawners.Therefore, the study recommends the optimum harvest size of the species between 15.8 and 19.3 cm, to ensure the sustainability of the whitespot sandsmelt fishery.

Key words: Biometric, Hypoallometric, Mega-spawners, Pinguipedidae, Protogynous hermaphrodite

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Introduction

Fishes belonging to the family Pinguipedidae (Sandperches) are known to inhabit sandy bottoms around the coral reef lagoons and slopes. The family comprises seven genera and 101 valid species around the world (Fricke *et al.,* 2024). Globally, *Parapercis* is the predominant genus of this family comprising 26 valid species of which, 14 species persist in the coastal waters of India (Suresh kumar and Idreesbabu, 2023). *Parapercis alboguttata* (Gunther, 1872) commonly termed whitespot sandsmelt is a demersal species under the family Pinguipedidae and order Labriformes. It is popularly called *"Lal Bhungar"* in Gujarat (India). Globally, the species is distributed in the Persian Gulf waters to India, Philippines, Indonesia and Australia (Cantwell, 1964). In India, the species was first identified from the Kovalam coast (Kerala) (Sreenivasan and Lazarus, 1976) and later recorded from Mumbai coast (Maharashtra) (Pillai and Somavanshi, 1979). Further, it was observed that *P. alboguttata* population has moderately increased throughout the south-west coast of India (Ramachandran *et al.,* 2002; Kumar *et al.,* 2020).

The species feeds on small teleosts, larval crustaceans, squid tentacles and gastropod shells (Ramachandran *et al.,* 2002). They are mostly landed in the bycatch of commercial trawlers operated off Veraval coast at 50-120 m depth but do not form a commercial fishery along this region due to low market value and thus it is wholly used for fishmeal production (personal communication with fishermen). Morphological traits such as morphometric and meristic characteristics are the backbone of ichthyo-taxonomy. They provide the preliminary source of information for any further investigation (Suyani *et al.,* 2021). Quantitative evaluation of growth characteristics *i.e.,* length-length and length-weight relationships of fish is one of the most crucial parameters of biometric analyses. These elements are important in studying the habitat and health conditions of fishin their natural environment and further examination of the improvement of fish stocks (Jawad and Al-Janabi, 2016). Analysis of life-history characteristics of fish helps in understanding the ecosystem health for its long-term sustainability and provides a key framework for devising strategies for the management of an exploited fish population (Khatun *et al.,* 2022). Besides, condition factors are contemplated as an analytical measure of the fish population's overall physiological status, health and success. In addition, relative weight (W_R) and form factor ($a_{3.0}$) values proclaim prey-predator relationships and body shape of fish in natural marine space, respectively (Froese, 2006).

The size at first sexual maturity (L_m) and optimum catchable length (L_{opt}) are fundamental tools for critical size regulation of fishing gear and the elimination of juveniles and mega-spawners in the fishery (Mawa *et al.,* 2021). Size-based reference points are used to monitor the stock status of species exploitation and can serve as a framework for preventing growth and recruitment overfishing, determining the selectivity pattern, and developing harvest management regulations (Froese, 2004; Cope and Punt, 2009). Preliminary studies were conducted on the biological aspects and head morphometry of *P. alboguttata* from Malabar Coast (Ramachandran *et al.,* 2002; Gop *et al.,* 2020) and Oman Coast (Jawad *et al.,* 2012), henceforth no reports are available on the biometric and life-history parameters. Hence, the current study was envisaged for the first time to offer detailed and comprehensive information on the sex ratio, biometric analysis, and life-history priors of *P. alboguttata* from the North-eastern Arabian Sea.

Materials and Methods

Study area and sampling: A total of 439 specimens (192 females and 247 males) of *Parapercis alboguttata* were collected randomlyon a fortnightly basis from the bycatch landings of multi-day trawlers (25-40 mm mesh size) operated along the Veraval fishing harbour (20°54'27" N, 70°23'02" E), Gujarat (India), northeastern Arabian Sea (Fig. 1) from September 2022 to August 2023 except in fishing ban period during June-July 2023 declared by the Department of Fisheries, Government of India. The collected fresh specimens were transported in chilled condition to the laboratory of the Department of Fisheries Resource Management, College of Fisheries Science, Kamdhenu University, Veraval for further detailed examination. The species was identified following the conventional taxonomic keys (Gunther, 1876; Das *et al.,* 2016).A graduated Vernier Caliper was used to measure the total length (TL) (nearest to 0.1 cm) and anelectronic weighing balance (Atom Incorporation, Mumbai, India) was used to measure thetotal weight (TW) (accuracy 0.01 g) of each individual. After anatomizing the fish, the gastrointestinal tract, pyloric caeca, liver, gas bladder and gonads were taken out and eviscerated weight (EW) was recorded.

Sex ratio and size structure: The females and males were segregated based on the presence of ovary and testis and sex ratio by different months and size groups was evaluated. The ratio of females to males was tested using a Chi-square test (χ^2) at $p \leq 0.05$. The size-frequency distribution of *P. alboguttata* was constructed through 1.0 cm class intervals of total length for both sexes.

Morphometric and meristic characteristics: Morphometric and girth characteristics such as total length (TL), standard length (SL), pre-dorsal length (PDL), pre-pectoral length (PPL), pre-ventral length (PVL), pre-anal length (PAL), trunk length (TKL), head length (HL), snout length (SNL),eye diameter (ED), eye middle dark portion (EMDP), inter-orbital distance (IOD), post-orbital length (POL), upper jaw length (UJL), lower jaw length (LJL), dorsal fin base length (DFBL), anal fin base length (AFBL), pectoral fin length (PFL), ventral fin length (VFL), caudal fin length (CFL), caudal fin depth (CD), caudal peduncle length (CPL), caudal peduncle depth (CPD), ventral to anal length (VAL), body depth maximum (BDM), length of 4th dorsal spine (L4DS), body girth through mid-eye (G1), body girth through gill-cover (G2) and maximum body girth (G3) were recorded separately for each sex to the nearest 0.1 cm using graduated Vernier Caliper and measuring tape following standard procedure (Naseeba *et al.,*

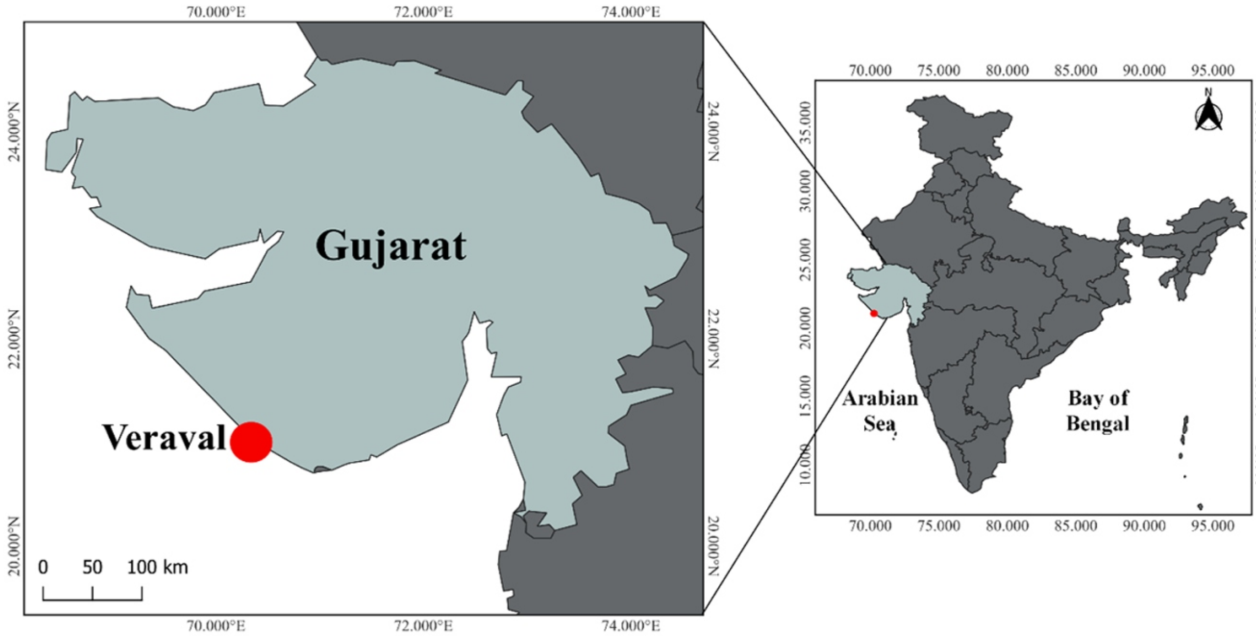

Fig. 1: Representation of study map area Veraval fishing harbour, Gujarat (India), North-eastern Arabian Sea (the map was prepared using QGIS version 3.36.3).

2020). A univariate Analysis of Variance (ANOVA) was carried out to test the significant difference in morphometric variables between male and female fishes at $p \leq 0.05$ (Labidi *et al.,* 2021). The descriptive statistics and index of morphometric (IM) (equation 1) of all the morphometric parameters were estimated (Heneish and Rizkalla, 2021):

$$IM = \frac{\text{Morphometric character}}{\text{Total Length/Head Length}} \times 100 \quad \text{eq. 1}$$

Various morphometric characteristics were grouped into three classes based on their range differences in IM: genetically (<10%), intermediate (10-15%), and environmentally (>15%) controlled characters (Johal *et al.,* 1994). The fin formula was determined based on meristic counts.

Length-length relationships (LLRs), length-weight relationships (LWRs) and weight-weight relationships (WWRs): The relationships between different length and girth measurements were established by both linear regression (Y = a + *bX*) and allometric (log Y = *a* + *b* log X) equations (Ragheb, 2022). The correlation coefficient (r) and coefficient of determination (r^2) were evaluated to adjudge the degree of correlation between the variables and stability of morphometric characters. In linear relationships, based on r value different morphometric variables were grouped into three classes viz., high (>0.90), good (0.75 to 0.90) and moderate (0.50 to 0.75) correlation (Kaur and Rawal, 2017). The length-weight relationships (LWRs) were fitted separately for each sex using the least square method (TW = a × TL^b) (Froese, 2006). Extreme anomalies were obliterated by constructing a log-log plot of length-weight pairs. The r^2 and 95% confidence interval values of a and b were enumerated. Further, significant disparity in b values between males and females was tested using one-way analysis of covariance (ANCOVA). A student's t-test (t_s) was executed to test the null hypothesis of isometric growth (*b*=1 for LLRs and *b*=3 for LWRs) at $p \leq 0.05$: $t_s = (b-1)/S_b$ for LLRs and $t_s = (b-3)/S_b$ for LWRs. The total weight (TW) and eviscerated weight (EW) relationships was fitted separately for males, females and combined sexes using a linear regression prototype (EW = *a* + *b* TW).

Condition factors: The relative condition factor (K_n), Fulton condition factor (K_F), and allometric condition factor (K_A) were determined monthly following the standard equations given by Le Cren (1951), Fulton (1911) and Tesch (1971), respectively. Based on KA and intercept (a) value, individuals were grouped into three modified categories *viz.,* lean (K_A<a), fit (K_A=a) and plump (K_A>a) (Nima *et al.,* 2021). Average relative weight (W_R) was calculated using the formula W_R = (TW/TWs) × 100 (Froese, 2006). Where, TW = wet weight and TWs = predicted standard weight of the same individual (TWs = $a \times L^b$).

Form factor and life-history priors: The form factor (a3.0) value was determined using the equation $a_{3.0} = 10^{\log a - s(b-3)}$, where a and b are the regression parameters of LWRs and *s* is the regression slope of ln *a* versus *b* (Froese, 2006).The life-history priors such as asymptotic length ($L\infty$), asymptotic weight ($W\infty$), longevity (t_{max}), size at first sexual maturity (L_m), age at first sexual maturity

(t_m), growth performance index ($Ø'$), natural mortality (M_W), and optimum catchable length (L_{opt}) were analyzed using the equations (2–9) (equation 2–5, Froese and Binohlan, 2000; equation 6, King, 2007; equation 7, Pauly and Munro, 1984; equation 8, Then *et al.,* 2015; equation 9, Beverton, 1992):

$$\log L\infty = 0.044 + (0.9841 \times \log L_{max}) \quad \text{eq. 2}$$

$$W\infty = a \times L\infty^{b} \quad \text{eq. 3}$$

$$\log t_{max} = (0.9570 \times \log t_m) + 0.5496 \quad \text{eq. 4}$$

$$\log L_m = (0.8979 \times \log L\infty) - 0.0782 \quad \text{eq. 5}$$

$$t_m = \left(-\frac{1}{1}\right) \times \ln\left(1 - \frac{L_m}{L\infty}\right) \quad \text{eq. 6}$$

$$Ø = (\log K) + (2 \times \log L\infty) \quad \text{eq. 7}$$

$$M_W = 4.899 \times t_{max}^{-0.916} \quad \text{eq. 8}$$

$$L_{opt} = \left(\frac{3\,L\infty}{3 + \frac{M_W}{K}}\right) \quad \text{eq. 9}$$

where, L_{max} = maximum total length and K=growth coefficient.

Size-Based Indicators (SBIs): Three size-based reference points (Pmat, Popt and Pmega) were calculated for each sex using the equations (10–12) (Froese, 2004):

$$P_{mat} = \sum_{L_m}^{L_{max}} P_L \quad \text{eq. 10}$$

$$P_{opt} = \sum_{0.9\,L_{opt}}^{1.1\,L_{opt}} P_L \quad \text{eq. 11}$$

$$P_{mega} = \sum_{1.1L_{opt}}^{L_{max}} P_L \quad \text{eq. 12}$$

where, P_L is the percentage of fish in the catch in the length interval L.

The three elements of SBIs were added in equation (13) to generate P_{obj}, a composite indicator that may be utilized in multi-gear fisheries, where the assumption of trawl-like selectivity is often not realized.

$$P_{obj} = P_{mat} + P_{opt} + P_{mega} \quad \text{eq.13}$$

P_{obj} was further interpreted using the constructed decision tree based on a deterministic age-structured population dynamics model (Cope and Punt, 2009). The researchers found that P_{obj} was more closely associated with spawning biomass (SB) than any of the SBIs. They further delineated that various selectivity patterns in the fishery were associated to a range of P_{obj} values. Once a selectivity pattern based on P_{obj} is established, threshold values of P_{mat}, P_{obj} and L_m/L_{opt} ratio is compared with an empirically established reference point to reveal whether the stock is above or below the SB reference point (0.4SB = target reference point (TRP) or 0.25 SB = limit reference point (LRP)) corresponds to the overfished status of the fishery (Froese, 2004; Cope and Punt, 2009; Babcock *et al.,* 2013).

Statistical analyses: All the statistical analyses and data processing were done using IBM-SPSS 21.0, MS-Excel 2019, and PAST 4.03 software. One-way Analysis of Variance (ANOVA) supervened by Tukey-Kramer HSD test was employed to test the significant differences in K_n and K_F between months and size groups ($p \leq 0.05$). A Wilcoxon signed-rank test was utilized to adjudge the prey-predator status by comparing W_R with 100 at $p \leq 0.05$ (Anderson and Neumann, 1996).

Results and Discussion

The current study provides the first comprehensive biometric and life-history information on *Parapercis alboguttata* from the *North-eastern* Arabian Sea region. The average annual sex ratio (F:M) of *P. alboguttata* reported in the present investigation (1:1.29) was biased towards males and differed significantly ($p<0.05$) from the theoretical ratio (1:1) (Table 1). Comparatively male-biased sex ratio was documented in *Pinguipes brasilianus* (F:M = 1:1.28) from the Atlantic Ocean (Villanueva-Gomila *et al.,* 2015). Size-wise sex ratio indicated a significant ($p<0.05$) predominance of females in small-size

Table 1: Month-wise and size-wise variations in the sex ratio of *Parapercis alboguttata*

Month/ Size group (cm)	Sex ratio (F:M)	χ^2
Sept	1:2.20	4.50¶
Oct	1:1.94	4.79¶
Nov	1:0.79	0.58
Dec	1:1.33	1.14
Jan	1:1.06	0.06
Feb	1:1.33	1.14
Mar	1:1.13	0.13
Apr	1:0.78	0.50
May	1:1.27	0.47
Aug	1:2.18	4.83¶
Total	1:1.29	6.89¶
10-12	-	-
12-14	1:0.14	4.50¶
14-16	1:0.03	32.11¶
16-18	1:0.37	19.88¶
18-20	1:0.75	1.71
20-22	1:1.62	4.26¶
22-24	1:27.33	73.42¶
24-26	1:26.50	47.29¶
26-28	-	-

¶$p<0.05$

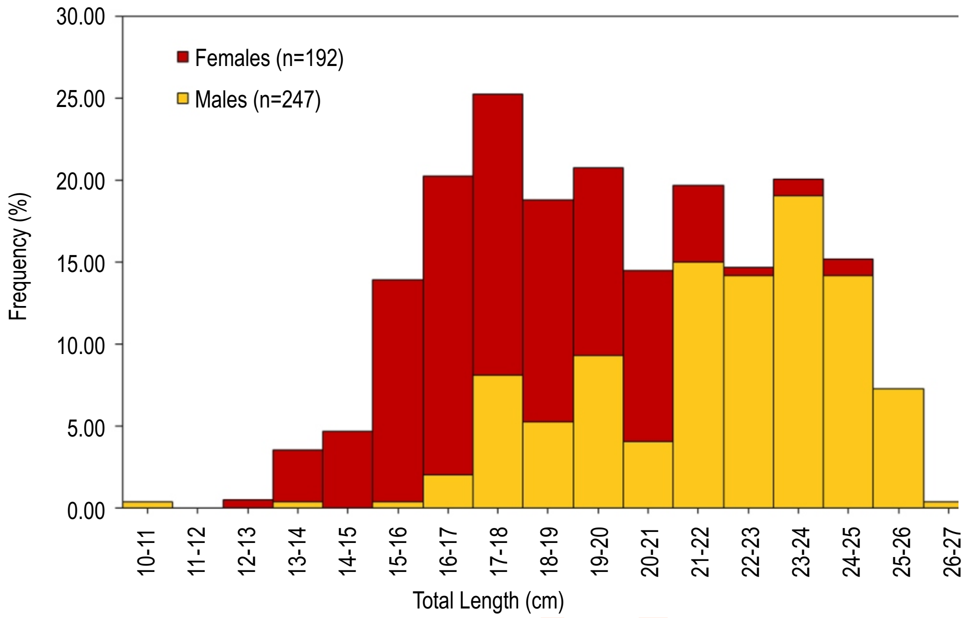

Fig. 2: Size-frequency distribution of females and males of *Parapercis alboguttata* from the North-eastern Arabian Sea.

groups and males in large-size groups (Table 1), which might be due to the intersexual (protogynous hermaphrodite) reproductive performance of the species because as the size of the protogynous fish increases, the sex ratio normally shifts from female-dominant to male-dominant (Taylor and McIlwan, 2012).

Similar protogynous hermaphroditism was observed in others and perch such as *Parapercis cylindrica, P. nebulosa, P. xanthozona, P. hexophtalma, P. clathrata* and *P. colias* (Stroud, 1982). This hermaphroditism might be driven by ecological and social factors such as size-advantage models, where larger males have greater reproductive success, and mate competition dynamics, which favor individuals with the ability to change sex to maximize reproductive opportunities. This can also be influenced by factors like population density and the operational sex ratio (Warner, 1984). Females were dominant in the catch upto 19.0 cm TL size group, while males were predominant in the large size groups (19.0-27.0 cm TL) with all individuals having TL≥24.1 cm being found males (Fig. 2).

The maximum TL (27.0 cm) of the species documented in the fishbase (Randall, 1995) was slightly higher than the current investigation (26.6 cm) signifying the wide size range of the sample collection for the analysis. A total of twenty-nine morphometric characters of *P. alboguttata* analyzed in this study exhibited statistically highly significant (Univariate ANOVA, p<0.001) differences between females and males. The average morphometric values of *P. alboguttata* males were significantly higher than females for all the morphometric characters (Table 2). The development of large-sized males could be linked to the polygynous mating behavior of the species (Stroud, 1982; Linde *et al.,* 2011). A high coefficient of variation (CV) (16-20%) was documented in the IOD and SNL, which could influence the foraging and defensive vision of the species. Similar high asymmetry in SNL and POL was recorded in *P. alboguttata* from the Oman coast (Jawad *et al.,* 2012). The index of morphometric (IM) value suggested restricted species distribution as most characterstics were found genetically controlled (range difference <10%) for both males and females (Table 2). However, head morphometrics were recorded in the intermediate to environmentally controlled category, recommending that these characters are most vulnerable to changes in the environmental conditions, which might be useful for solving the taxonomic ambiguity among the *Parapercis* species. The fin formula can be determined as: D: X, 22; P: 16-18; V: I, 5-6; A: I, 18, 15-18 gill rakers on first gill arch. The meristic traits in the present study were found in conformity with previous reports of Pillai and Somavanshi (1979), Yamanaka *et al.* (2011) and Hanif *et al.* (2021). However, in the present study, 18 anal fin rays were recorded, but Peristiwady and Achmad (2009) documented 19 anal fin rays. These minor changes in meristic traits could be due to genetic or ecological factors (Lindsey, 1988).

In the present study, all the morphometric characters showed a higher rate of change in males compared to females (Table 3). Therefore, investigating the degree of sexual dimorphism can help in perceiving a species' ecological and social adaptation and facilitate precise identification of the species.The linear relationships between TL vs. SL and TL vs. DFBL were highly significant (p<0.01) and best-fit model (r>0.99), however, relatively high CV and low correlation in CD suggested phenotypic responsiveness in the caudal fin region as a result of

Table 2: Morphometric measurements of females and males of *Parapercis alboguttata*

Variables		Morphometric measurements (cm)					Index of morphometric (%)			
		Female			Male		Female		Male	
	Range	Mean ± SD	%CV	Range	Mean ± SD	%CV	Range (%)	Difference	Range (%)	Difference
TL	12.9-24.0	17.66 ± 2.20	12.43	10.4-26.6	21.76 ± 2.59	11.88		In Total Length (TL)		
SL	11.1-20.4	14.93 ± 1.90	12.74	9.0-22.5	18.19 ± 2.16	11.89	81.71-87.50	5.79$^{\Omega}$	80.58-87.41	6.83$^{\Omega}$
PDL	3.2-6.1	4.43 ± 0.56	12.67	2.6-7.0	5.44 ± 0.65	12.00	23.60-26.67	3.06$^{\Omega}$	21.93-27.12	5.19$^{\Omega}$
PPL	3.5-6.5	4.80 ± 0.61	12.80	2.8-7.2	5.90 ± 0.71	12.03	24.84-29.26	4.41$^{\Omega}$	25.00-33.71	8.71$^{\Omega}$
PVL	2.9-5.9	4.09 ± 0.55	13.37	2.4-6.5	5.07 ± 0.64	12.60	21.08-27.43	6.34$^{\Omega}$	20.00-25.97	5.97$^{\Omega}$
PAL	5.5-9.9	7.27 ± 0.89	12.19	4.3-11.0	8.80 ± 1.04	11.82	38.57-43.68	5.11$^{\Omega}$	38.22-42.74	4.51$^{\Omega}$
TKL	7.5-14.0	10.08 ± 1.26	12.49	6.2-15.0	12.36 ± 1.48	11.99	48.94-60.29	11.36$^{\delta}$	53.72-60.96	7.25$^{\Omega}$
HL	3.3-6.5	4.75 ± 0.60	12.67	2.8-7.6	5.81 ± 0.70	12.12	24.38-29.26	4.88$^{\Omega}$	24.59-33.14	8.55$^{\Omega}$
DFBL	6.5-12.3	9.01 ± 1.14	12.60	5.6-13.4	11.09 ± 1.34	12.07	48.65-53.19	4.54$^{\Omega}$	48.55-54.64	6.09$^{\Omega}$
AFBL	4.4-8.8	6.40 ± 0.82	12.83	3.8-9.6	7.96 ± 0.97	12.17	33.85-38.22	4.37$^{\Omega}$	33.89-39.18	5.29$^{\Omega}$
PFL	1.9-3.5	2.47 ± 0.31	12.56	1.5-3.8	2.93 ± 0.35	11.95	11.93-16.23	4.30$^{\Omega}$	10.87-15.57	4.70$^{\Omega}$
VFL	1.9-3.7	2.68 ± 0.29	10.71	1.8-3.7	3.10 ± 0.32	10.21	12.92-17.86	4.94$^{\Omega}$	12.02-17.31	5.29$^{\Omega}$
CFL	1.9-3.9	2.78 ± 0.36	12.80	1.5-4.8	3.51 ± 0.47	13.36	13.29-18.56	5.27$^{\Omega}$	13.33-19.13	5.79$^{\Omega}$
CD	1.1-3.5	2.44 ± 0.37	14.95	1.1-4.4	3.07 ± 0.53	17.14	8.09-18.13	10.04$^{\delta}$	7.91-18.57	10.66$^{\delta}$
CPL	0.9-2.1	1.35 ± 0.23	17.11	0.9-2.5	1.69 ± 0.26	15.40	5.84-11.19	5.35$^{\Omega}$	6.11-12.24	6.13$^{\Omega}$
CPD	0.7-1.4	1.02 ± 0.13	13.18	0.6-1.6	1.27 ± 0.16	12.84	5.10-6.47	1.37$^{\Omega}$	5.09-6.52	1.43$^{\Omega}$
VAL	2.1-4.3	3.15 ± 0.38	11.93	1.9-4.7	3.70 ± 0.45	12.10	15.00-20.93	5.93$^{\Omega}$	14.29-20.11	5.82$^{\Omega}$
BDM	1.6-3.6	2.34 ± 0.31	13.24	1.2-4.4	2.91 ± 0.39	13.53	10.84-17.05	6.21$^{\Omega}$	10.68-17.05	6.37$^{\Omega}$
L4DS	0.8-1.7	1.20 ± 0.16	13.48	0.7-1.9	1.43 ± 0.18	12.62	5.56-9.04	3.49$^{\Omega}$	4.58-7.80	3.22$^{\Omega}$
G1	4.9-9.5	6.73 ± 0.77	11.52	4.0-10.8	8.23 ± 1.00	12.17	32.70-43.31	10.61$^{\delta}$	30.87-42.29	11.42$^{\delta}$
G2	5.5-11.3	7.71 ± 0.92	11.89	4.7-13.0	9.51 ± 1.14	12.01	39.43-50.39	10.96$^{\delta}$	38.86-50.39	11.53$^{\delta}$
G3	5.2-11.0	7.47 ± 0.91	12.23	4.4-12.5	9.28 ± 1.18	12.67	37.37-50.39	13.02$^{\delta}$	36.84-48.45	11.61$^{\delta}$
								In Head Length (HL)		
SNL	0.8-2.2	1.29 ± 0.22	16.94	0.5-2.6	1.77 ± 0.29	16.62	21.95-34.38	12.42$^{\delta}$	17.86-37.70	19.85$^{\times}$
ED	0.7-1.4	1.03 ± 0.12	11.49	0.6-1.5	1.18 ± 0.14	11.81	17.19-25.64	8.45$^{\Omega}$	16.42-25.00	8.58$^{\Omega}$
EMDP	0.4-0.7	0.53 ± 0.06	12.12	0.3-0.7	0.60 ± 0.07	12.27	8.47-13.51	5.04$^{\Omega}$	7.81-14.29	6.47$^{\Omega}$
IOD	0.4-1.4	0.78 ± 0.15	19.90	0.2-1.6	1.09 ± 0.19	17.44	10.00-27.45	17.45$^{\times}$	7.14-24.19	17.05$^{\times}$
POL	1.5-3.1	2.27 ± 0.29	12.77	1.2-3.5	2.70 ± 0.32	11.73	40.00-54.55	14.55$^{\delta}$	40.79-53.33	12.54$^{\delta}$
UJL	1.0-2.3	1.55 ± 0.24	15.46	0.7-2.7	2.02 ± 0.29	14.43	22.22-36.73	14.51$^{\delta}$	25.00-40.98	15.98$^{\times}$
LJL	1.1-2.5	1.69 ± 0.24	14.37	0.8-3.0	2.20 ± 0.32	14.34	26.83-39.06	12.23$^{\delta}$	28.57-43.08	14.51$^{\delta}$

SD = standard deviation; CV = coefficient of variation (%); $^{\Omega}$Genetically (<10%); $^{\delta}$Intermediate (10-15%); $^{\times}$Environmentally (>15%) controlled character

changing Arabian Sea parameters such as sea surface temperature and tropical cyclone heat potential (Nirmal *et al.,* 2023). The allometric comparison of the species helps to understand the scaling relationship between different body parts because the growth of one dimension does not necessarily occur at the same rate. It also provides insights into species' ecological roles and evolutionary strategies (Li *et al.,* 2023). In males, negative allometric growth (b<1) was recorded in PAL, PFL, VFL, VAL, L4DS, G1 and G2 concerning TL, while all other morphometric variables showed isometric growth (p>0.05; b=1). But in females, three characters (SL, PVL and AFBL) showed positive allometric growth (p<0.05; b>1). However, in relation to HL, positive allometric growth (b>1) was recorded in SNL, IOD, UJL and LJL and negative allometric growth (b<1) was found in ED, EMDP and POL for both sexes (Table 4). This dimorphic characteristic might be due to differences in the type and quality of food preferred by the individual, male-male competition, social and reproductive roles, and non-biological factors that affect the well-being of the species (Minos *et al.,* 2008). The present examination of length-length relationships of *P. alboguttata* from the Gujarat coast provides the first comprehensive data in the world.

The detailed regression statistics of LWRs of *P. alboguttata* is outlined in Table 5. The outcome of covariance analysis showed no significant disparity in the regression coefficient (b) between male and female specimens (Levene's test for homogeneity of slopes, F-ratio=0.319; p>0.05), hence a pooled relationship was calculated as follows: $TW = 0.00916\ TL^{2.9246}$. The b value of combined sexes suggests that the species becomes skinny with increase in size (t-test, p<0.05; b<3). A similar hypoallometric growth (b<3) condition was recorded by Gop *et al.* (2020) from Kanyakumari waters (Tamil Nadu), but Ramachandran *et al.* (2002) noted isometric growth (b=1) from Mumbai waters (Maharashtra). These variations in growth

Table 3: Linear regression analysis of length-length relationships (LLRs) of *Parapercis alboguttata*

Equations	**Female**			**Male**		
	a	***b***	***r***	***a***	***b***	***r***
SL = a + b TL	0.1346	0.8297	0.9922[£]	-0.2879	0.8613	0.9945[£]
PDL = a + b TL	0.0531	0.2478	0.9808[£]	-0.0281	0.2525	0.9873[£]
PPL = a + b TL	0.0998	0.2664	0.9712[£]	-0.0708	0.2759	0.9853[£]
PVL = a + b TL	-0.1134	0.2383	0.9642[£]	-0.1979	0.2430	0.9745[£]
PAL = a + b TL	0.1496	0.3978	0.9882[£]	0.2206	0.3993	0.9887[£]
TKL = a + b TL	0.0171	0.5675	0.9893[£]	0.1028	0.5646	0.9852[£]
HL = a + b TL	0.0854	0.2631	0.9661[£]	-0.0150	0.2697	0.9843[£]
DFBL = a + b TL	-0.0691	0.5128	0.9909[£]	-0.0668	0.5139	0.9941[£]
AFBL = a + b TL	-0.1032	0.3709	0.9890[£]	-0.1383	0.3701	0.9903[£]
PFL = a + b TL	0.3740	0.1175	0.8674[§]	0.1763	0.1297	0.9191[£]
VFL = a + b TL	0.6628	0.1121	0.9154[£]	0.5513	0.1205	0.9223[£]
CFL = a + b TL	-0.1029	0.1661	0.9158[£]	0.1072	0.1510	0.9339[£]
CD = a + b TL	-0.0799	0.1447	0.7112[¥]	0.2215	0.1257	0.7460[¥]
CPL = a + b TL	-0.0347	0.0794	0.7875[§]	-0.1579	0.0854	0.8116[§]
CPD = a + b TL	-0.0416	0.0603	0.9560[£]	-0.0136	0.0584	0.9555[£]
VAL = a + b TL	0.2113	0.1606	0.9262[£]	0.2977	0.1617	0.9438[£]
BDM = a + b TL	-0.0698	0.1372	0.8996[§]	0.0968	0.1271	0.8999[§]
L4DS = a + b TL	0.0732	0.0625	0.8935[§]	0.0509	0.0648	0.8833[£]
G1 = a + b TL	0.6114	0.3501	0.9043[£]	1.0062	0.3239	0.9180[£]
G2 = a + b TL	0.7177	0.4039	0.9147[£]	1.0091	0.3794	0.9091[£]
G3 = a + b TL	0.3840	0.4088	0.8991[§]	0.8275	0.3763	0.9042[£]
SNL = a + b HL	-0.3784	0.3695	0.8856[§]	-0.3063	0.3361	0.9259[£]
ED = a + b HL	0.2028	0.1680	0.8499[§]	0.2140	0.1713	0.8730[§]
EMDP = a + b HL	0.1109	0.0835	0.8039[§]	0.1180	0.0864	0.8120[§]
IOD = a + b HL	-0.2540	0.2310	0.8571[§]	-0.2662	0.2195	0.8553[§]
POL = a + b HL	0.2088	0.4290	0.9534[£]	0.0858	0.4600	0.9550[£]
UJL = a + b HL	-0.2603	0.3933	0.9479[£]	-0.2289	0.3734	0.9404[£]
LJL = a + b HL	-0.2778	0.4263	0.9522[£]	-0.1405	0.3840	0.9549[£]

*p<0.01; a = intercept; b = slope; r = correlation coefficient; [£]High correlation (>0.90); [§]Good correlation (0.75-0.90); [¥]Moderate correlation (0.50-0.75)

patterns may be due to sample size, length composition and sampling time (Rajesh *et al.,* 2020). Weight-weight relationships (WWRs) help in analyzing the yield and biomass of the population as well as the feeding and reproductive conditions of the fish. The b value of WWRs of males, females, and pooled data reveal statistically highly significant (p<0.001) relationships. The linear relationships between the weight parameters were enumerated as follows: *EW = -0.4524 + 0.9378 TW* (r = 0.9970) for females, *EW = 0.3746 + 0.9376 TW* (*r* = 0.9969) for males and *EW = -0.5561 + 0.9467 TW* (r = 0.9981) for combined sexes.

The average relative weight of *P. alboguttata* was found 6.5% greater than the eviscerated weight indicating a higher yield for the entire eviscerated fish (93.5%). The WWRs calculated in this study form the novel report from the world, hence no comparisons were made. The ratio of length and weight is utilized to examine the condition indices of fishes because the body mass of fish is closely associated with its length and these could be used as a proxy to measure the stored energy reserves of the species (Neumann *et al.,* 2013). Average monthly K_n of *P. alboguttata* was found near integrity (around 1) for both the sexes suggesting identical condition of the species (Table 6). Mean K_F calculated in different months was found<0.8 indicating skinny fish (Table 6). Mean deviations in K_F in different months (Tukey HSD, p<0.05) may be correlated to temperature fluctuations over seasons, nutrient availability and energy transformation from somatic to gonadal development. The monthly variations in the corporeal status based on K_A of *P. alboguttata* suggest that the composition of lean fishes was found higher from October to December and April to August in females and August to October and February to March in males (Fig. 3). The present study highlights more fluctuations of lean fishes in different months, which might be linked to the spawning season of the species (Ozvarol *et al.,* 2010). Similar correlations were made in *Tenualosa ilisha* from Bangladesh waters (Nima *et al.,* 2021). The presence of spawning capable specimens in varied proportions all through the year suggests that *P. alboguttata* spawns multiple times in a year which confirms the multiple spawning behaviors of *P. Brasilianus* (Villanueva-Gomila *et al.,* 2015). The average value of W_R was not significantly different from 100 (Wilcoxon signed

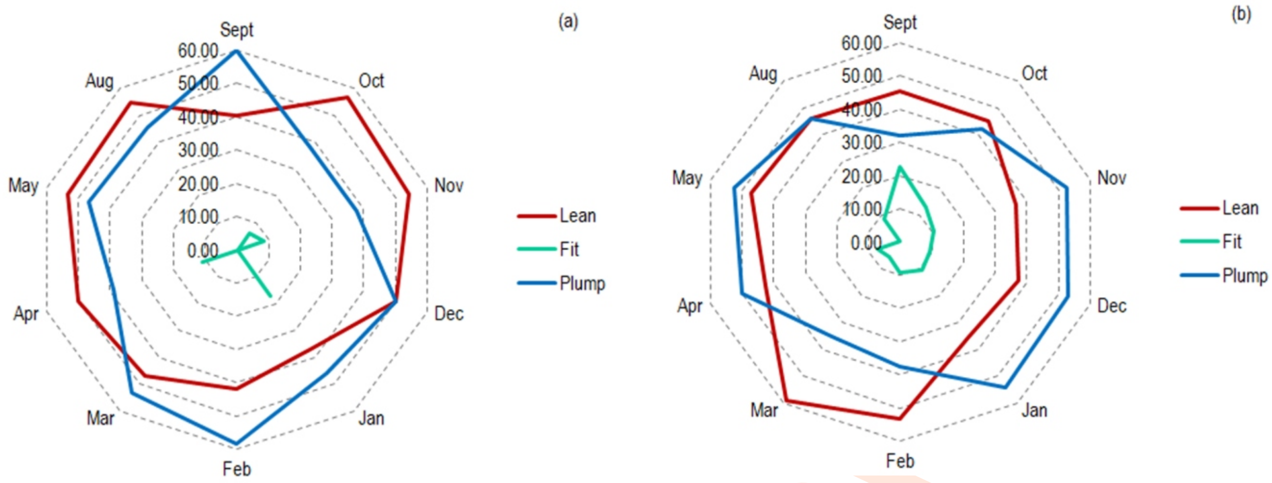

Fig. 3: Monthly changes in the corporeal status based on allometric condition factor (K_A) of females (a) and males (b) of *Parapercis alboguttata.*

Table 4: Allometric regression analysis of length-length relationships (LLRs) of *Parapercis alboguttata*

Equation	Female			Male		
	a	*b*	r^2	*a*	*b*	r_2
logSL = a + blogTL	-0.0969	1.0189*	0.9887	-0.0598	0.9865	0.9862
logPDL = a + blogTL	-0.6089	1.0067	0.9745	-0.5867	0.9888	0.9676
logPPL = a + blogTL	-0.5830	1.0138	0.9695	-0.5458	0.9840	0.9488
logPVL = a + blogTL	-0.6847	1.0396*	0.9486	-0.6602	1.0204	0.9402
logPAL = a + blogTL	-0.3444	0.9672*	0.9771	-0.3692	0.9822*	0.9802
logTKL = a + blogTL	-0.2273	0.9868	0.9695	-0.2349	0.9922	0.9816
logHL = a + blogTL	-0.5743	1.0029	0.9675	-0.5459	0.9793	0.9412
logDFBL = a + blogTL	-0.3068	1.0115	0.9886	-0.2956	1.0021	0.9834
logAFBL = a + blogTL	-0.4773	1.0290*	0.9792	-0.4571	1.0154	0.9808
logPFL = a + blogTL	-0.7364	0.9048*	0.8374	-0.6836	0.8598*	0.7813
logVFL = a + blogTL	-0.5600	0.7925*	0.8458	-0.5357	0.7681*	0.8494
logCFL = a + blogTL	-0.7567	0.9619	0.8633	-0.8548	1.0462	0.8562
logCD = a + blogTL	-0.8196	0.9664	0.5559	-0.9590	1.0784	0.5290
logCPL = a + blogTL	-1.2418	1.0983	0.6537	-1.1152	1.0033	0.6617
logCPD = a + blogTL	-1.2684	1.0231	0.9127	-1.2790	1.0339	0.9237
logVAL = a + blogTL	-0.6334	0.9078*	0.8844	-0.6836	0.9361*	0.8809
logBDM = a + blogTL	-0.8145	0.9489	0.8003	-0.9176	1.0327	0.8419
logL4DS = a + blogTL	-1.1337	0.9709	0.7841	-1.1107	0.9465*	0.8171
logG1 = a + blogTL	-0.2222	0.8420*	0.8335	-0.3178	0.9216*	0.8380
logG2 = a + blogTL	-0.1810	0.8564*	0.8166	-0.2537	0.9206*	0.8620
logG3 = a + blogTL	-0.2198	0.8765*	0.8076	-0.3227	0.9641	0.8365
logSNL = a + blogHL	-0.7242	1.2311*	0.8641	-0.7328	1.2799*	0.8181
logED = a + blogHL	-0.5337	0.8061*	0.7631	-0.5642	0.8312*	0.7523
logEMDP = a + blogHL	-0.8139	0.7926*	0.6623	-0.8514	0.8190*	0.6693
logIOD = a + blogHL	-1.0339	1.3594*	0.7401	-1.0223	1.3817*	0.7455
logPOL = a + blogHL	-0.2977	0.9660	0.9126	-0.2825	0.9344*	0.9156
logUJL = a + blogHL	-0.5929	1.1535*	0.8680	-0.5924	1.1748*	0.9034
logLJL = a + blogHL	-0.5093	1.0858*	0.9029	-0.5468	1.1620*	0.9137

*$p<0.05$; a = intercept; b = slope; r^2 = coefficient of determination

Table 5: Length-weight relationships (LWRs) of *Parapercis alboguttata* from the North-eastern Arabian Sea

Parameters	Female	Male	Pooled
Sample size (N)	192	247	439
TL range (cm)	12.9–24.0	10.4–26.6	10.4–26.6
Total Weight (TW) range (g)	14.92–119.99	7.56–149.98	7.56–149.98
Regression parameters			
Intercept (a)	0.014 (0.012–0.018)	0.006 (0.005–0.007)	0.009 (0.008–0.010)
Slope (b)	2.7583 (2.6948–2.8218)	3.0669 (3.0148–3.1189)	2.9246 (2.8898–2.9595)
Coefficient of determination (r^2)	0.9824	0.9879	0.9892
Student's t-test			
|t-value|	7.532*	2.536*	4.258*
Growth type	–Allometric	+Allometric	–Allometric
*p<0.05; CI = confidence interval			

*p<0.05; Value in parenthesis indicates 95% confidence interval

Table 6: Monthly changes in relative (K_n) and Fulton (K_F) condition factor of *Parapercis alboguttata*

Months	K_n		K_F	
	Female	Male	Female	Male
September	1.0023 ± 0.0709	1.0023 ± 0.0689	0.7264 ± 0.0514^{a}	0.7513 ± 0.0585^{bcd}
October	1.0030 ± 0.0810	1.0023 ± 0.0699	0.7172 ± 0.0664^{a}	0.7212 ± 0.0520^{ab}
November	1.0031 ± 0.0814	1.0023 ± 0.0690	0.7502 ± 0.0628^{ab}	0.7380 ± 0.0517^{abc}
December	1.0013 ± 0.0523	1.0023 ± 0.0684	0.8002 ± 0.0419^{b}	0.7930 ± 0.0567^{d}
January	1.0024 ± 0.0705	1.0033 ± 0.0816	0.7158 ± 0.0523^{a}	0.7099 ± 0.0578^{ab}
February	1.0025 ± 0.0712	1.0034 ± 0.0836	0.7402 ± 0.0562^{ab}	0.7587 ± 0.0632^{bcd}
March	1.0027 ± 0.0756	1.0040 ± 0.0921	0.7434 ± 0.0576^{ab}	0.7376 ± 0.0677^{abc}
April	1.0022 ± 0.0696	1.0016 ± 0.0581	0.7654 ± 0.0535^{ab}	0.7876 ± 0.0465^{cd}
May	1.0039 ± 0.0910	1.0027 ± 0.0749	0.7372 ± 0.0674^{a}	0.7593 ± 0.0589^{bcd}
August	1.0007 ± 0.0408	1.0024 ± 0.0704	0.7215 ± 0.0434^{a}	0.6889 ± 0.0484^{a}

$^{a-d}$Values succeeded by different superscripts represent significant differences between months (p<0.05); mean ± SD

Table 7: Form factor ($a_{3.0}$) and life-history traits of *Parapercis alboguttata*

Parameters	Female	Male	Combined sexes
Maximum Total Length (cm) (L_{max})	24.0	26.6	26.6
Form factor ($a_{3.0}$)	0.0070	0.0073	0.0072
Asymptotic length ($L\infty$) (cm)	25.3	27.9	27.9
Asymptotic weight ($W\infty$) (g)	109.62	160.80	155.43
Size at first sexual maturity (L_m) (cm)	15.2	16.6	16.6
Age at first sexual maturity (t_m) (years)	0.92	0.90	0.90
Longevity (t_{max}) (years)	3.3	3.2	3.2
Growth performance index (Ø')	2.77	2.86	2.86
Natural mortality (M_W) (year^{-1})	1.66	1.68	1.68
Optimum catchable length (L_{opt}) (cm)	15.8	17.5	17.5

ranked test, p>0.05), connoting an identical territory with stable prey-predator abundance in the environment. The analyzed $a_{3.0}$ value (0.0070-0.0073) for the population of *P. alboguttata* signifies an elongated type of body shape (Froese, 2006). The present study can act as a model for future investigations on body shape as no references were found in this genera/species. The novel information on crucial life-history parameters of *P. alboguttata* is presented in Table 7. The $L\infty$ and $W\infty$ of combined

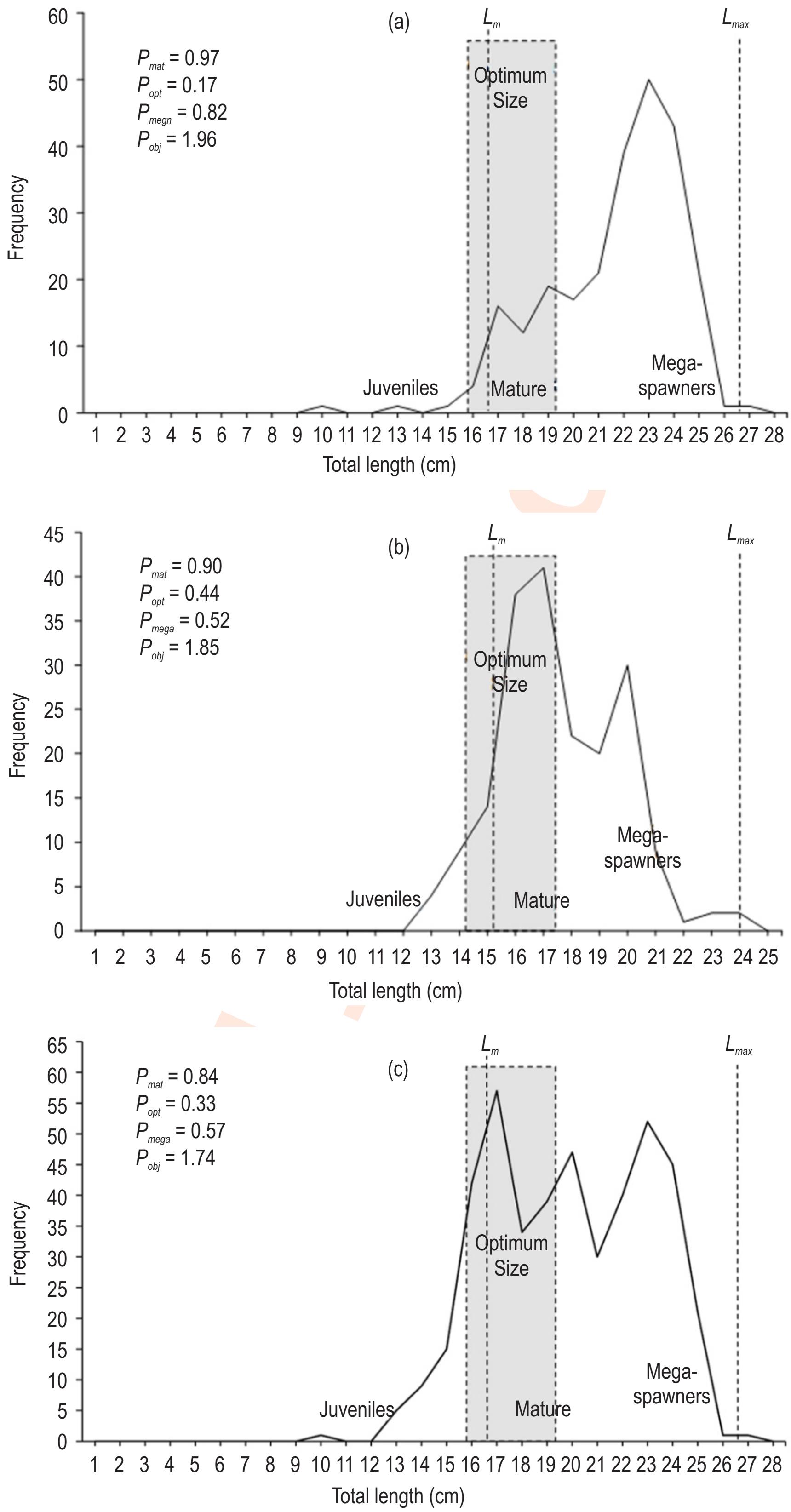

Fig. 4: Relative position of size indicators of males (a), females (b) and pooled (c) *Parapercis alboguttata.*

sexes were evaluated as 27.9 cm and 155.43 g respectively. Size at first sexual maturity (L_m) is an important life-history parameter required for devising the strategies for responsible fisheries management and development of a basic measure for the elimination of juveniles in the exploited fishery resources (Meshram *et al.,* 2021). The smaller L_m in females in this study (15.2 cm) confirms the protogynous hermaphrodite behavior of *P. alboguttata.* Similar findings of females maturing at smaller lengths and protogynous hermaphroditism was recorded in other reef-associated species such as *Chlorurus capistratoides, Scarus flavipectoralis* and *Scarus rivulatus* from Indonesia coast (Tuwo *et al.,* 2021). The t_m was calculated as 0.90 years for males and 0.92 years for females. The longevity of tropical fishes generally varies from two to three years (Qasim, 1973), which is in agreement with the present study for *P. alboguttata* (3.2 years) from the Gujarat coast. The average *Ø'* and M_W of combined individuals were determined as 2.86 and 1.68 year^{-1} respectively. The average L_{opt} of *P. alboguttata* was calculated as 15.9 cm for females and 17.5 cm for males and combined sexes.

The L_{opt} is a crucial parameter that helps in mesh size regulation of fishing gear by allowing the undersized fish to escape from the net (Khatun *et al.,* 2022). In this study, catch composition was examined to ascertain the percentage of mature fish (P_{mat}), optimally sized fish (P_{opt}) and mega-spawners (P_{mega}) using the sustainability indicators (Froese, 2004). To prevent growth overfishing, all catches should be kept within the 10% range of L_{opt} and percentage of P_{mat} should be as high as possible. The outcomes of current investigation show that mature fish made bulk of the catch (84–97%), but the percentage of optimally sized fishes was found lower (17–44%) (Fig. 4). Additionally, the fishery of any species depends on older fishes known as mega-spawners, due to their high fecundity rate and ability to prolong the reproductive cycle and lifespan (Froese, 2004). The higher percentage of mega-spawners in this study (52–82%) indicates continuous removal of large-size fish from the stock. The selectivity pattern of *P. alboguttata* should target length classes (L_{opt} ± 10% of L_{opt}) between 14.2 cm and 17.4 cm for females and between 15.8 cm and 19.3 cm for males and combined sexes for maximized production. Furthermore, the application of the decision tree depict that the SB of combined sex was below the TRP and LRP. Thus, the present study suggests size regulation of *P. alboguttata* fishery along the studied region.

The present investigation forms the baseline information on biometric and life-history priors of whitespot sandsmelt from the North-eastern Arabian Sea, which could be utilized as primary information for future studies on feeding and reproductive biology, population dynamics, otolith and nutritional profiling. The constructed LLRs, LWRs and WWRs will be useful in converting the length and weight measurements in the field or on-board studies. Furthermore, size-based indicators for combined sex advise that fish smaller than 15.8 cm and larger than 19.3 cm should not be collected for sustainable exploitation. The provided length indicators will be helpful in judicious fisheries management measures.

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