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Life-history Traits of the Blacktrip sardinella, *Sardinella melanura* (Clupeidae) in the Gwadar, Balochistan Coast, Pakistan

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The present study describes the first complete and comprehensive description on life-history traits of *Sardinella melanura* including length-frequency distributions (LFDs), length-weight relationships (LWRs), condition factors (allometric condition, K_A; Fulton's condition, K_F; relative condition, K_R), and relative weight (W_R) in the Gwadar, Balochistan Coast, Pakistan. Additionally, form factor ($a_{3.0}$) using available *a* and *b* regression parameters of LWRs and size at first sexual maturity (L_m) using available maximum length for 07 *Sardinella* spp. in 23 water-bodies were calculated. Seasonal samples of *S. melanura* were collected from the Gwadar, Balochistan Coast, Pakistan using gill nets during July 2013 to June 2014. Total length (TL) was measured to nearest 0.1 cm using digital slide calipers and total body weight (BW) was measured using an electronic balance with 0.1 g accuracy for each individual. A total of 600 individuals of *S. melanura* were analyzed, where minimum and maximum TL was 12.5 cm and 23.00 cm, respectively and BW was 16.5g and 114.8 g, correspondingly. Highest number (25.83%) of its population stands at 17.00 cm to 18.00 cm size group. The *b* value of LWR indicated negative allometric growth in the population. All the condition factors (K_A, K_F, K_R, and W_R) were significantly correlated with TL and BW ($P < 0.001$). W_R showed significant difference from 100 ($P < 0.001$) representing imbalanced population in presence of prey and predator. In addition, the $a_{3.0}$ for *S. melanura* was 0.0078. The size at first sexual maturity (L_m) was 14.43 cm in TL of *S. melanura* in the Gwadar, Balochistan coast, Pakistan.

[**Keywords**: *Sardinella melanura*, growth pattern, condition factors, form factor, size at first sexual maturity, Gwadar, Balochistan Coast, Pakistan]

Introduction

The *Sardinella melanura* (Cuvier, 1829) is a marine, pelagic-neritic and amphidromous fish of the family Clupeidae. This fish is found in the south-west and south-east Asian countries including India, Iran, Indonesia and Pakistan[1]. Blacktip sardinella is also reported from Australia[2]. *S. melanura* is locally known as Polli in Pakistan[3], Tamban in Philippines[4] and Blacktrip sardinella in India[5].

Information on life-history traits of fishes like *S. melanura* is crucial for the sustainable management and conservation in their natural habitats[6,7]. In particular, length-weight relationships (LWRs) have been used broadly in stock assessment models and to compare the life histories of certain species among regions and other biological aspects of fish population dynamics[8,9]. In addition, the information/data on weight and length can also provide important clues to climate and environmental changes and change in fishery practices[10]. Moreover, biometric relationships including Fulton's condition factor (K_F) and relative condition factor (K_R) are vital biological parameters for fishes, from which the state of health of stocks can be assumed[11]. Furthermore, relative weight (W_R) is one of the most popular indexes for assessing condition of fishes in recent years[12]. Moreover, form factor ($a_{3.0}$) is used to verify whether the body shape of a given species is notably different from others[13]. The size at first sexual maturity is very significant to find out the factors that affect the spawning size of a population[14].

The life-history traits including length-frequency distributions (LFDs)[7,14,15], length-weight relationships (LWRs)[16,17,18], form factor ($a_{3.0}$)[19,20] and size at first sexual maturity (L_m)[17,19,21] and condition factors[22,7,23] for different fish species of Indian sub-continent are well documented. To the best of the authors' knowledge, there is no previous information on life-history traits of *S. melanura* in-details from the Gwadar, Balochistan coast, Pakistan or else except few studies on LWR[24,25], LFD[26] and morphology[1]. Information on the population structure of *S. melanura* is needed for appropriate management and initiate conservation measures for this important species in the Balochistan Coast, Pakistan. Therefore, this study reported the first complete and informative description on life-history traits including length-frequency distributions (LFDs), length-weight relationships (LWRs), condition factors (allometric, K_A; Fulton's, K_F; relative, K_R), relative weight (W_R), of *S. melanura* using a number of individuals with various body sizes from the Gwadar, Balochistan Coast, Pakistan. Additionally, form factor ($a_{3.0}$) and size at first sexual maturity (L_m) of a total of 07 spp. in world-wide 23 different water-bodies were calculated using available literature.

Materials and Methods

This study was conducted in the water of Gwadar, Balochistan Coast, Pakistan (longitude 25.20^0 N and latitude 62.19^0 E) from July 2013 to June 2014. A total of 600 individuals of *S. melanura* were sampled using gill nets (length: 19m, width: 3m and mesh size: 33mm). The fresh samples were immediately chilled in ice on site and fixed with 10% buffered formalin upon arrival in the laboratory.

All morphometric measurements were taken according to Fishbase[27]. For each individual, total length (TL) was measured to the nearest 0.1 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan) and total body weight (BW) was measured using an electronic balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.1 g accuracy.

The LWR was calculated using the equation: $W = a \times L^b$, where W is the body weight (g) and L is the total length (cm). The parameters a and b were estimated by linear regression analyses based on natural logarithms: $\ln(W) = \ln(a) + b \ln(L)$. Additionally, 95% confidence limits of a and b and the co-efficient of determination (r^2) were estimated. Prior to the regression analyses of ln BW on ln TL, ln-ln plots of length and weight values were performed for visual inspection of outliers, with extremes being omitted from the regression analyses[13]. A t-test was used to confirm whether b values obtained in the linear regressions were significantly different from the isometric value ($b = 3$)[28].

The K_A was calculated using the equation[29] as $K_A = W/L^b$, where W is the BW, L is the TL and b is the LWR parameter. The K_F was calculated using the equation: $K_F = 100 \times (W/L^3)$, where W is the body weight (BW) in g, and L is the total length (TL) in cm. The scaling factor of 100 was used to bring the K_F close to unit. The relative condition (K_R) for each individual was calculated by the equation[30] as $K_R = W/(a \times L^b)$, where W is the BW, L is the TL, a and b are the LWRs parameter.

The W_R was calculated using the equation[13] as: $W_R = (W/W_S) \times 100$, where W is the weight of a particular individual and W_S is the predicted standard weight for the same individual as calculated by $W_S = a*L^b$, where a and b values were obtained from the relationships between TL and BW. The form factor ($a_{3.0}$) for this species was calculated by the equation[13] as: $a_{3.0} = 10^{log\ a-s(b-3)}$, where a and b are regression parameters of LWRs and s is the regression slope of *ln a vs. b*. The L_m of *S. melanura* was calculated using the equation, $\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$, by [31].In addition, the regression parameters a and b for LWRs of different species of *Sardinella* were obtained from available literature in the Fishbase[27] and else to estimate their form factor.

The size at first sexual maturity (L_m) of *S. melanura* in the Gwadar, Balochistan Coast was calculated using the empirical equation, $\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$[31] based on maximum observed length. In addition, the maximum lengths of different species of Sardinella were obtained from available literature in the Fishbase[27] and they were used to estimate the size at first sexual maturity in different water-bodies.

The Microsoft® Excel-add-in-DDXL and GraphPad Prism 5 software were used to conduct statistical analyses. Tests for normality of each group were conducted by visual assessment of histograms and box plots and confirmed with the Saprio-Wilk normality-test. The non-parametric Wilcoxon signed rank test was used to compare the mean W_R with 100[33]. Additionally, Spearman signed rank test was used to verify the correlations of condition-factors

with TL and BW. All statistical analyses were considered significant at 5% ($P<0.05$).

Results

Descriptive statistics on length and weight measurements with mean values and 95% confidence levels of *S. melanura* are presented in the Table 1. The LFDs of *S. melanura* showed that TL varied between 12.5 cm and 23.00 cm. Maximum population stands at 17.00 cm to 18.00 cm TL size group (Fig. 1). The LFDs showed that the population was not normally (Shapiro-Wilk normality test, $p<0.001$) distributed in the Gwadar, Balochistan Coast, Pakistan. On the other hand, the body weight varied from 16.5g to 114.8 g.

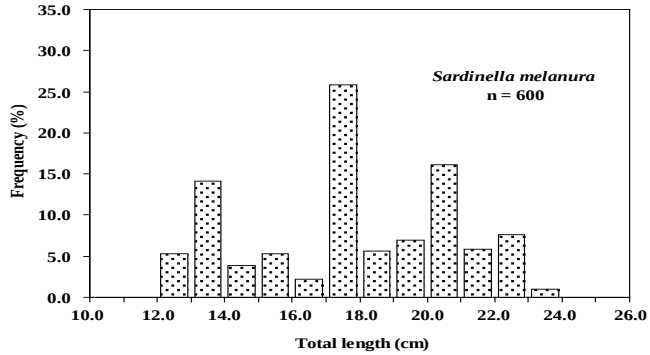

Fig. 1. Total length frequency distribution of *Sardinella melanura* from the Gwadar, Balochistan Coast, Pakistan

Sample sizes (n), regression parameters and 95% confidence intervals for a and b of the LWRs, coefficients of determination (r^2) and growth type of *S. melanura* are given in Table 2 and Fig. 2. The b (2.823) values for TL-BW relationships negative allometric growth pattern in the population of *S. melanura* from Gwadar, Balochistan Coast, Pakistan.

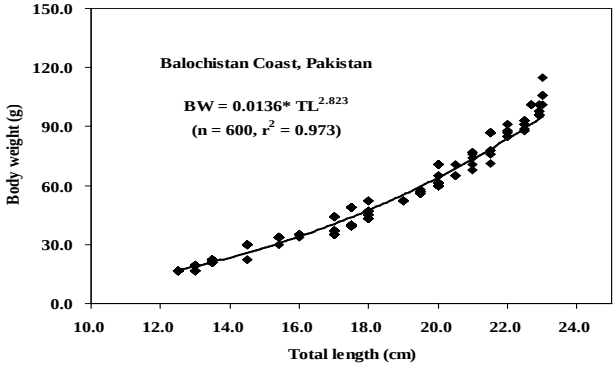

Fig. 2. Relationship between total length (TL) and body weight (BW) of *Sardinella melanura* from the Gwadar, Balochistan Coast, Pakistan

All the condition factors including K_A, K_F, K_R and W_R with mean values and 95% CL are presented in Table 3. Additionally, the relationships of condition factors with TL and BW are presented in Table 4. The W_R was significantly different from 100 (Wilcoxon signed rank test, $P < 0.001$) indicating the imbalance population on the presence of predator and prey. In addition, the relative weight (W_R) in relations to body sizes is shown in Fig. 3. These results indicated problems with surplus prey or low predator density in the Gwadar, Balochistan Coast for smaller sizes (TL ≤ 17.00) of *S. melanura*. However, inverse condition was found when body sizes of *S. melanura* increased (>17.0 cm TL).

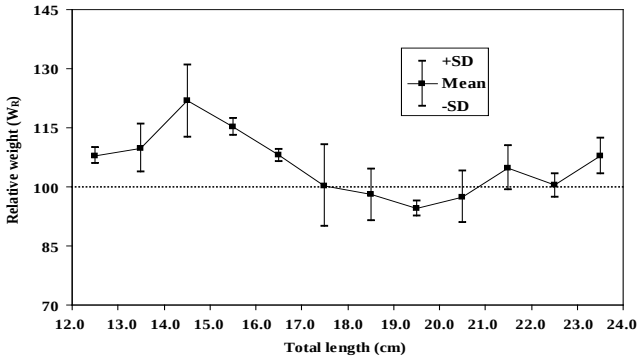

Fig. 3. The relative weight (W_R) in relations to body sizes of *Sardinella melanura* from the Gwadar, Balochistan Coast, Pakistan

The calculated $a_{3.0}$ of *S. melanura* in the Balochistan Coast, Pakistan with other *Sardinella* spp. of world-wide different water-bodies is presented in Table 5. In our study the $a_{3.0}$ was 0.0078 for *S. melanura*.

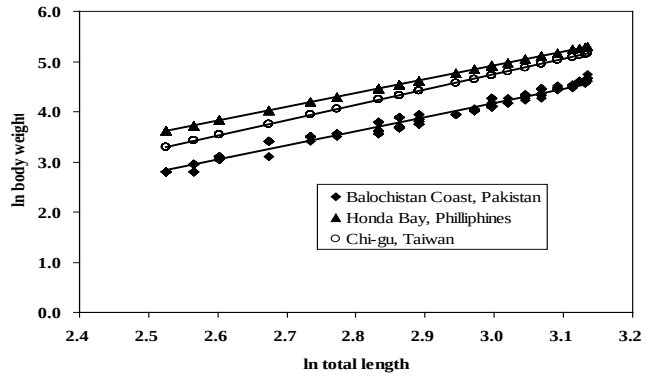

Fig. 4. Total length (mm) and body weight (g) relationships (ln W = ln a + b ln L) of *Sardinella melanura* from the Gwadar, Balochistan Coast, Pakistan (Present study), (ii) Honda Bay, Phillphines[24] (iii) Chi-gu black-spoonbill, Taiwan[25].

The calculated L_m was 14.43 cm TL (95% CL = 10.55 – 17.07 cm) for *S. melanura* in our study. In addition, the calculated L_m of *Sardinella* spp. in the world-wide water-bodies is given in Table 6.

TABLE 1– Descriptive statistics on the length (cm) and weight (g) measurements of *Sardinella melanura* (Cuvier, 1829) from the Gwadar, Balochistan Coast, Pakistan

Measurements	Sex	*n*	Min	Max	Mean ± SD	95% CL
TL	Unsexed	600	12.5	23.00	17.58 ± 2.98	17.34 – 17.81
BW			16.5	114.8	47.98 ± 22.71	46.16 – 49.80

TL, total length; BW, body weight; *n*, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

TABLE 2– Descriptive statistics and estimated parameters of the length-weight relationships (LWRs) (BW= $a \times TL^b$) of *Sardinella melanura* (Cuvier, 1829) from the Gwadar, Balochistan Coast, Pakistan and available parameters of LWRs in other water-bodies.

Equation	Sex	*n*	*a*	*b*	r^2	GT	References
$BW = a \times TL^b$		29	0.0126	3.040	0.890	+A	24
$BW = a \times TL^b$	Combined	67	0.0358	2.750	0.874	-A	25
$BW = a \times TL^b$		600	0.0136	2.823	0.973	-A	Present study

n, sample size; *a*, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination; GT, growth type; -A, negative allometric

TABLE 3– Condition factors of *Sardinella melanura* (Cuvier, 1829) from the Gwadar, Balochistan Coast, Pakistan

Condition factors	Sex	*n*	Min	Max	Mean ± SD	95% CL
K_A			0.006	0.008	0.0069 ± 0.0006	0.0068 – 0.0070
K_F	Combined	600	0.714	0.984	0.8240 ± 0.0730	0.8200 – 0.8300
K_R			0.883	1.246	1.0300 ± 0.1000	1.0200 – 1.0400
W_R			88.29	124.60	103.210 ± 9.590	102.44 – 103.98

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values; K_A, allometric condition factor; K_F, Fulton's condition factor; K_R, relative condition factor; W_R, relative weight

Table 4– Relationships of condition factor with total length (TL) and body weight (BW) of *Sardinella melanura* (Cuvier, 1829) from the Gwadar, Balochistan Coast, Pakistan

Relationships	r_s value	95% CL of r_s	*p* value	Significance
TL *vs.* K_A	-0.269	-0.3434 to -0.1904	$P < 0.001$	***
TL *vs.* K_F	-0.364	-0.4330 to -0.2899	$P < 0.001$	***
TL *vs.* K_R	-0.364	-0.4330 to -0.2899	$P < 0.001$	***
TL *vs.* W_R	-0.364	-0.4330 to -0.2899	$P < 0.001$	***
BW *vs.* K_A	-0.142	-0.2215 to -0.0600	$P < 0.005$	***
BW *vs.* K_F	-0.241	-0.3174 to -0.1620	$P < 0.001$	***
BW *vs.* K_R	-0.241	-0.3174 to -0.1620	$P < 0.001$	***
BW *vs.* W_R	-0.241	-0.3174 to -0.1620	$P < 0.001$	***

K_A, allometric condition factor; K_F, Fulton's condition factor; K_R, relative condition factor; W_R, relative weight; CL, confidence limit for mean values; r_s, spearman rank correlation of coefficient; ***, highly significant

Discussion

This study was collected a large number of specimens for *S. melanura* with various body sizes. However, it was not possible to collect Blacktip sardinella < 12.5 cm TL, which can be assigned due to the selectivity of fishing gears/ mesh[14]. Maximum TL was 23.0 cm

during this study, which is higher than the maximum recorded value of 12 cm TL in Iran[34] while smaller than 25.56 cm TL ≠ 21cm SL) in Philippines [35] **(**see Table 6**)**. The variations in the recorded maximum TL of *S. melanura* in different waters could be attributed to the nonexistence of bigger-sized individuals in the populations in fishing grounds/ area[21]. In addition, the variations in the fishing gear used and the selectivity on the target species may greatly influence the size distribution of the individuals caught resulting in highly biased estimations of the various population parameters including the maximum size[23]. Information on maximum length/size is essential to calculate the population parameters including asymptotic length and growth coefficient of fishes and shell-fishes, which is vital for fisheries resource conservation and management[21]. No previous records of LFD of this species could be traced from the related literature, inhibiting the comparison with previous results.

The present study revealed that the calculated *b* value (2.823) lies between 2.50 and 3.50[13]. In general and notwithstanding many deviations in fish forms between species, *b* is close to 3, designating that fish grow isometrically; values significantly different from 3.0 indicate allometric growth[29]. Thus the growth of *S. melanura* is negative allometric in the Gwadar, Balochistan Coast, Pakistan that means faster in length than in weight. Here, the slope was significantly different from the water bodies of Philippines[24] and Taiwan[25] ($p < 0.001$) (see Fig. 4). Such variations in the LWRs may be ascribed to differences in the physiology of the fishes[30], gonadal development, sex, health[36, 37] and feeding rate[38].

Here, four kinds of condition factors (K_A, K_F, K_R and W_R) have been used in our study that are rare in literature and all the condition factors can be used for the well being of this species in the waters of Balochistan Coast, Pakistan. Results indicated that all the condition factors were significantly correlated with TL and BW. In addition, the W_R indicates the presence of low predator and high prey for *S. melanura* in Balochistan Coast representing imbalanced condition. However, the condition factor derived from the LWR is a marker of the changes in food reserves, and the general fish health[39]. Because of no available references dealing with condition factors of this species, it was not possible to compare with our findings.

The form factor ($a_{3.0}$) can be used to prove whether the body shape of individuals in a given population or species is extensively different from others[13]. In our study the $a_{3.0}$ was 0.0078 for *S. melanura*. In addition this study calculated the $a_{3.0}$ of different *Sardinella* spp. from a number of water bodies using available literature for future comparison. No references dealing with the $a_{3.0}$ are available in the literature for *S. melanura*, therefore, the present investigation provides an important foundation for future study.

Studies on size at first sexual maturity (L_m) for *S. melanura* from Balochistan Coast, Pakistan are absent in the literature. This size parameter is of special awareness in fisheries management and is widely used as an indicator for minimum acceptable capture size[40]. The L_m for *S. melanura* was 14.43 cm TL in this study. Additionally, the L_m for 07 *Sardinella* spp. from 23 different water-bodies have been calculated using maximum length from available literature, which would be used for conservation regulations in its own habitat. Since there is no reference dealing with the size at sexual maturity (L_m) of *Sardinella* spp., this study will afford the basis for more detailed studies to find out the factors affecting the size at first sexual maturity and spawning size in different populations of *Sardinella* spp.

Conclusion

This research imparts an important baseline on life-history traits of *S. melanura* including length-frequency distribution, length-weight relationships, condition factors, and relative weight. Additionally, this study gives valuable information on form factor and size at first sexual maturity for a total of 07 spp. in different 23 water-bodies, which would be very effective for their sustainable management and conservation in any coastal and marine ecosystems.

Table 5— The calculated form factor $a_{3.0}=10^{log\ a\ -\ s\ (b-3)}$ of *Sardinella* spp. in the world-wide different water-bodies

Species name	*a*	*b*	Water-body	References	$a_{3.0}$
Sardinella aurita	0.0014	3.280	Peninsula and Dardanelles, Turkey	41	0.0034
	0.0104	3.120	Cape Verde	42	0.0151
	0.0043	3.120	Eastern Adriatic Sea, Croatia	43	0.0063
	0.0057	3.160	Northeast region, Mexico	44	0.0094
	0.0062	3.076	Gökceada Island Turkey	45	0.0079
	0.0040	3.160	River Cetina estuary, Croatia	46	0.0066
	0.0068	2.990	Balearic IslandsSpain	47	0.0066
	0.0333	2.272	Northern Sea of Marmara, Turkey	48	0.0034
	0.0087	2.950	Strymon estuaryGreece	49	0.0074
S. fimbriata	0.0451	2.580	Honda Bay, Taiwan	24	0.0121
S. gibbosa	0.0158	2.784	western Indonesia	40	0.0080
	0.0083	2.969	El-Ghardaqa, Red Sea, Egypt	51	0.0075
	0.0202	2.950	Honda Bay, Taiwan	24	0.0173
S. lemuru	0.0012	3.752	Southern coasts, Indian Ocean	49	0.0126
	0.0262	2.790	Honda Bay Philippines,	24	0.0136
	0.0095	3.599	Daya Bay, China	52	0.0618
S. longiceps	0.0135	2.926	West coast of India	53	0.0107
	0.0001	2.645	Ratnagiri,Maharastra, India	54	0.0000
S. maderensis	0.0140	2.827	Apese, Lagos Nigeria	55	0.0082
	0.0064	3.250	Cape Verde Island	41	0.0140
S. melanura	0.0358	2.750	Honda Bay, Philippines	24	0.0164
	0.0126	3.040	Chi-gu black-spoonbill, Taiwan	25	0.0143
	0.0136	2.823	Balochistan Coast, Pakistan	Present study	0.0078

a and *b* are regression parameters of length-weight relationships; $a_{3.0}$, form factor

Table 6— The calculated size at first sexual maturity (L_m) of *Sardinella* spp. in the world-wide different water-bodies

Species name	Max TL	Water-body	References	L_m	95% CL of L_m
Sardinella aurita	24.6	Peninsula &Dardanelles, Turkey	41	14.28	11.19-18.19
	24.0	Cape Verde Island	42	13.96	10.95-17.77
	17.0	Eastern Adriatic Sea, Croatia	43	10.18	8.09-12.82
	13.0	Northeast region, Mexico	44	7.96	6.40-9.94
	26.2	Gökceada Island, Turkey	45	15.13	11.82-19.30
	17.0	River Cetina estuary, Croatia	46	10.18	8.09 – 12.82
	23.8	Balearic Islands, Spain	47	13.86	10.87-17.63
	16.8	Northern Sea of Marmara, Turkey	48	10.07	8.01-12.68
	20.0	Strymon estuary, Greece	49	11.82	9.33-14.95
S. fimbriata	11.5 *	Honda Bay, Taiwan	24	7.12	5.75-8.85
S. gibbosa	19.5	western Indonesia	50	11.54	9.13-14.60
	14.5	El-Ghardaqa, Red Sea, Egypt	51	8.80	7.04-11.03
	12.0 *	Honda Bay, Taiwan	24	7.40	5.97-9.22
S. lemuru	17.0	Southern coasts, Indian Ocean	49	10.18	8.09-12.82
	15.0 *	Honda Bay, Philippines,	24	9.08	7.25-11.39
	13.0 *	Daya Bay, China	52	7.96	6.40-9.94
S. longiceps	24.0	West coast of India	53	13.96	10.95-17.77
	21.2	Ratnagiri,Maharastra, India	54	12.46	9.82-15.80
S. maderensis	28.5	Apese, Lagos; Nigeria	55	16.34	12.73-20.91
	29.0	Cape Verde Island	41	16.60	12.92-21.25
S. melanura	20.3	Honda Bay, Philippines	24	11.98	9.46-15.16
	12.0	Chi-gu black-spoonbill, Taiwan	25	7.40	5.97-9.22
	23.0	Balochistan Coast, Pakistan	Present study	13.43	10.55-17.07

*Standard length; TL, total length; Max, maximum; L_m, size at first sexual maturity; CL, confidence limit for mean values

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