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Morphological measurements, length weight relationship and relative condition factor (*Kn*) of Obtuse barracuda *Sphyraena obtusata* (Cuvier, 1829) from South-eastern Arabian Sea

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The study investigated morphometric and meristic measurements, length-weight relationship (LWR) and relative condition factor (*Kn*) of the *Sphyraena obtusata* from south-eastern Arabian Sea from August 2019 to March 2020. Three hundred and fifty two specimens having a length and weight range of 16.5 – 30.1 cm and 29.54 – 155.20 g, respectively were analyzed for morphological measurements (13 morphometric and 11 meristic), LWR and relative condition factor. The maximum correlation were existed between standard length ($r > 0.985$), fork length ($r > 0.979$) and pre-dorsal length 1 ($r > 0.942$) among the various morphometric variables. A disparity in relative growth was noticed among the morphometric traits. The Regression coefficient *b* value clearly indicates that growth of all the morphometric characters were isometric in connection with the total length, except for pelvic length (negative allometric), body depth (positive allometric) and caudal depth (positive allometric) ($p < 0.01$). The length-weight relationship of the individual sexes (male, female) and pooled data is indicated as $W = 0.02275\ L^{2.6033}$, $W = 0.01786\ L^{2.6815}$ and $W = 0.01945\ L^{2.6541}$ having the value of coefficient of determination (r^2) as 0.9566, 0.9696 and 0.9658, respectively. The '*b*' values for both males and females divulge negative allometric growth ($p < 0.05$). There was no significant difference for the relative condition factor (*Kn*) among the months and size groups.

[**Keywords**: Allometry, Meristic characters, Obtuse barracuda, Regression coefficient]

Introduction

Fishes which are known as barracuda (Sphyraenidae: Perciformes) and sea-pikes lives in pelagic waters and exists mainly in the Indo-Pacific areas. They are considered as one of the commercially important fish resources due to their superior quality as tasty food fishes. The only genus, *Sphyraena* of the family Sphyraenidae comprises 28 valid species globally[1] of which, 11 species exists in the Indian waters[2]. These fishes are sold in local markets and are exported in fresh, frozen or dried form. Barracudas form considerable contribution to the marine fisheries resources of India with an annual landing of 34,010 tons, which contributed to 0.92 % of total marine fish catch of the country[3]. Barracudas are harvested by various fishing nets like mechanized trawlers, gill nets, and motorized ringseines[4].

The obtuse barracuda, *Sphyraena obtusata* (Cuvier, 1829) is one of the commercially important small sized species of barracudas generally inhabits in bays, estuarine waters, rocky areas and seagrass beds[5]. For this species, a maximum size of 55 cm has been reported[6]. It is a voracious carnivorous feeder, actively hunt small fishes[4].

Morphometric analysis of fishes serves as an important tool in fisheries management as they are useful in quantifying a trait of evolutionary implication, and also helps to detect the changes in the shape, assume some developmental history of an individual organism (ontogeny), function, or evolutionary relations[7]. Morphometric parameters of a fish species has main role to ensure any discrepancies within the same species of diverse geographic areas[8]. Variations in availability of food, sex, predator-prey relationship, physico-chemical and environmental condition leads to the phenotypic disparities in morphological traits within the same species[9]. Similarly, analysis of length-weight relationships (LWRs) of fishes provides information on biology, ecology, physiology, population dynamics, fisheries assessment, and general conditions of the studied population. Mathematically, LWR describes the relationship between fish length and body mass, which is helpful in translating length annotations into weight approximation to furnish the measure of biomass[10]. Relative condition factor (*Kn*) quantify the deviation of an organism from the average body mass, which provides information on growth and well-being of the fish[11].

Studies on morphometry of *S. obtusata* are scanty, and available reports are limited to the waters of Bombay[12], Black Sea[13] and Sri Lanka[14]. Therefore, an investigation on morphological measurements and relative condition factor was done to study the basic biological information and growth pattern of *S. obtusata*, a commercially important fishery resource from the Southeastern Arabian Sea, as an imperative means to aid fishery managers.

Materials and Methods

Three hundred and fifty two specimens of *S. obtusata* landed by trawl boats at Mangaluru (12°50'54" N; 74°50'11" E) and Malpe (13°21'14" N; 74°41'52" E) fishing harbors (Fig. 1) were collected once in fifteen days during the period of eight months (August 2019 to March 2020). The collected specimens were iced, packed and then shifted to the laboratory of Fisheries Resources and Management, College of Fisheries, Mangaluru for further analysis. In the laboratory, the total length (TL) nearest to

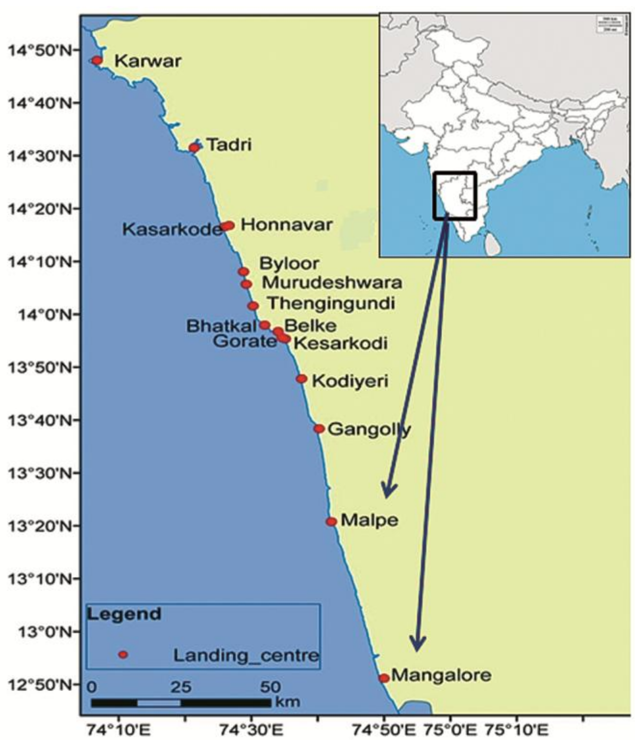

Fig. 1 — Study area and the specimens of *Sphyraena obtusata* collected along south-eastern Arabian Sea

0.1 cm and the total body weight (W) nearest to 0.1 g was taken individually. The morphometric measurements such as total length (TL), standard length (SL), fork length (FL), pre-dorsal length 1 (PDL1), pre-dorsal length 2 (PDL2), pre-anal fin (PAL), pre-ventral fin (PVL), pre-pectoral fin (PPL), head length (HL), snout length (SnL), eye diameter (ED), body depth (BD) and caudal depth (CD) were documented to the nearest cm following the standard procedure[15-17]. The number of dorsal, ventral and anal fin spines and number of rays in dorsal, pectoral, ventral, anal and caudal fins were counted. Further, number of gill rakers on first gill arch and lateral line scales was also counted. The morphometric measurements, calculated in relation to the percentage of total length were analyzed statistically for range, mean, median, standard error, standard deviation, and coefficient of variation. On the basis of differences in the range, various morphometric characters were classified into three categories[18], with a modification of the criterion given by Vladykov[19] as genetically (< 10 %), intermediate (10-15 %) and environmentally (> 15 %) controlled characters. The entire morphometric measurements were taken from the left of the fish body part and represented in percentage of total length. The total length was considered as independent variable, while all other traits as dependent variables. The correlation coefficient (r) was estimated to perceive the extent of linear relationship among the two variables. The range, mean, median, mode, standard error, standard deviation, and coefficient of variation estimated for meristic counts were subjected to standard statistical analysis.

The LWR were determined separately for different sexes following the formula specified by Le Cren[20]: $W = a\text{TL}^b$. This relationship can also be articulated in the logarithmic form as $\log W = \log a + b \log L$; where W = total weight (g), TL = total length (cm), a = intercept, and b = slope (growth coefficient). By performing a log-log plot of the length-weight pairs from the regression analysis, extreme outliers were removed. Co-efficient of determination (r^2) and 95 % confidence limit (CL) were estimated for the parameters a and b. To determine the significant difference of b values between the males and females, One-way ANCOVA (analysis of covariance) was employed[21]. The estimated "b" values were tested for the growth pattern of individual as well as pooled sexes against the value of 3 at 5 % level of significance using the student t-test[22]. Slope and intercept were estimated through linear regression by plotting logW against logL.

Monthly relative condition factor (*Kn*) was determined individually for both the sexes and for different size groups (2 cm intervals) to understand the wellbeing of the species by using the formula[20]: $Kn = W_o/W_c$; where, W_o = observed weight and W_c = calculated weight. All the statistical analyses were performed using the MS-Excel 2013 and IBM SPSS Statistics 21.0 package.

Results

Morphometric and meristic measurements

For morphometric and meristic investigations, three hundred and fifty two specimens of *S. obtusata* were analyzed. The statistical parameters for each morphometric measurements like range, mean, median, standard deviation (SD), standard error (SE), and coefficient of variation (CV) of *S. obtusata* are depicted in Table 1. The analysis of the data revealed a maximum CV in the body depth (21.67 %) followed by caudal depth (20.16 %) and eye diameter (14.66 %) whereas the lowest CV was recorded in pre-ventral length (10.22 %). Based on the correlation coefficient (*r*) and regression coefficient (*b*), comparison of different morphometric length measurements in relation with the total length of *S. obtusata* were made. Standard length was correlated to the maximum extent (r = 0.985) and caudal depth was correlated to the minimum extent (r = 0.708) while, all other morphometric characters had good and moderate correlation to total length (Table 2). Scatter plot was drawn for the relationships of different morphometric characters against the total length and is presented in Figure 2. Out of twelve characters, two (PPL and ED) were found to be controlled by genetical factors having range difference of < 10 %, eight (SL, PDL1, PAL, PVL, HL, SnL, BD and CD) were in intermediate category with range difference fluctuating between 10-15 %

Table 1 — Statistical analysis of different morphometric characters in *Sphyraena obtusata*

Statistical parameters	Range (cm)	Mean (cm)	Median (cm)	Standard error	Standard deviation	Coefficient of variation (%)
Total length (TL)	16.5-30.1	23.83	24.0	0.15	2.49	10.43
Standard length (SL)	14.2-26.0	20.27	20.5	0.13	2.13	10.51
Fork length (FL)	15.0-28.0	21.96	22.2	0.14	2.37	10.78
Pre-dorsal length-1 (PDL1)	6.0-11.0	8.75	8.9	0.06	0.94	10.71
Pre-dorsal length-2 (PDL2)	8.6-17.9	13.84	14.1	0.10	1.61	11.62
Pre-anal length (PAL)	9.9-19.0	14.54	14.6	0.10	1.60	11.02
Pre-ventral length (PVL)	5.6-10.2	8.16	8.2	0.05	0.83	10.22
Pre-pectoral length (PPL)	5.0-9.4	6.96	7.0	0.05	0.75	10.84
Head length (HL)	4.9-9.1	6.86	6.9	0.05	0.75	11.00
Snout length (SnL)	2.1-4.6	3.01	3.1	0.02	0.39	12.84
Eye diameter (ED)	0.8-1.8	1.19	1.2	0.01	0.18	14.66
Body depth (BD)	1.1-5.0	3.17	3.2	0.04	0.69	21.67
Caudal depth (CD)	1.8-5.2	3.53	3.5	0.04	0.71	20.16

Table 2 — Values of *a* and *b* constants in the linear regression of different morphometric characters on the total length together with respective r and r^2 values

Morphometric character	*a*	*b*	*r*	r^2	S.E.
Standard length (SL)	0.8660	0.9943	0.985	0.971	0.01049
Fork length (FL)	0.8843	1.0129	0.979	0.958	0.01286
Pre-dorsal length – 1 (PDL1)	0.4035	0.9699	0.942	0.888	0.02093
Pre-dorsal length – 2 (PDL2)	0.5820	0.9989	0.881	0.776	0.03251
Pre-anal length (PAL)	0.5817	1.0149	0.965	0.931	0.01674
Pre-ventral length (PVL)	0.4791	0.8939	0.914*	0.836	0.02399
Pre-pectoral length (PPL)	0.3276	0.9638	0.933	0.871	0.02249
Head length (HL)	0.3308	0.9557	0.919	0.844	0.02488
Snout length (SnL)	0.1157	1.0268	0.830	0.688	0.04189
Eye diameter (ED)	0.0527	0.9824	0.724	0.524	0.05675
Body depth (BD)	0.0133	1.7193	0.769*	0.592	0.08661
Caudal depth (CD)	0.0376	1.4279	0.708*	0.501	0.08645

*$p < 0.01$; *a* - intercept; *b* - coefficient of regression; *r* - coefficient of correlation; r^2 - coefficient of determination; and S.E. - standard error of estimate

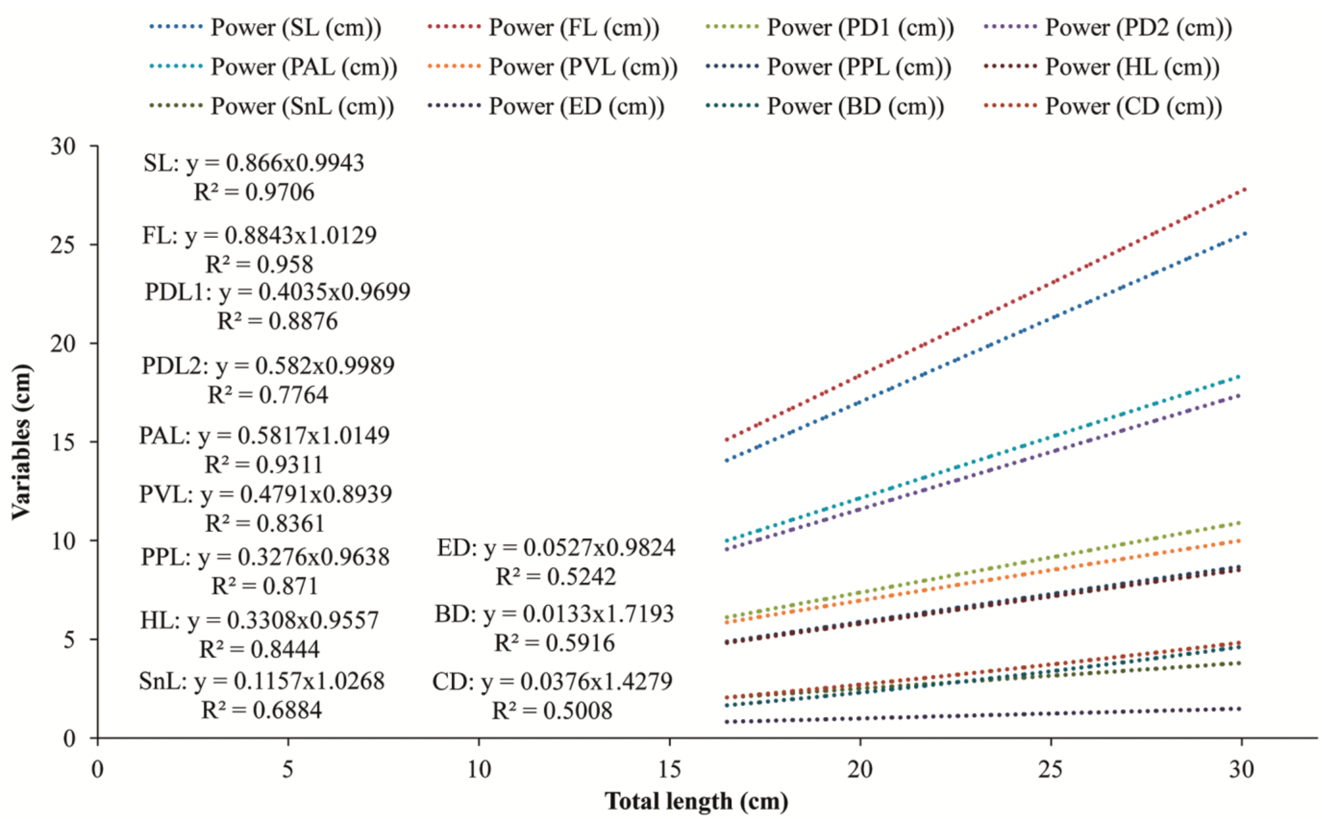

Fig. 2 — Relationship between various morphometric traits with total length in *Sphyraena obtusata*

Table 3 — Relationship between percentage body proportions vs. total length (TL) of *Sphyraena obtusata*

In % of total length (TL)	Range		Range difference (%)	Mean (%)	SD (%)
	Minimum (%)	Maximum (%)			
Standard length (SL)	80.45	92.13	11.67	85.07	1.59
Fork length (FL)	82.26	99.13	16.87	92.14	2.08
Pre-dorsal length – 1 (PDL1)	28.33	41.31	12.98	36.71	1.35
Pre-dorsal length – 2 (PDL2)	35.85	63.33	27.48	58.08	2.88
Pre-anal length (PAL)	52.31	66.09	13.78	61.00	1.81
Pre-ventral length (PVL)	31.12	42.67	11.55	34.27	1.55
Pre-pectoral length (PPL)	23.81	32.78	8.97	29.23	1.16
Head length (HL)	23.81	38.70	14.89	28.79	1.31
Snout length (SnL)	9.39	20.44	11.06	12.63	0.98
Eye diameter (ED)	3.93	6.72	2.79	5.01	0.52
Body depth (BD)	5.24	18.52	13.28	13.19	2.08
Caudal depth (CD)	8.30	20.88	12.58	14.76	2.28

and two characters (FL and PDL2) were observed to be environmentally controlled having range difference > 15 % (Table 3).

An analysis of meristic characters indicated that the number of spines in first dorsal fin were 5, 1 in second dorsal, 1 in ventral and 2 in anal fin. There were 9 rays in dorsal fin 2, 5 in ventral fin and 17 in the caudal fin. Two gill rakers on first gill arch remained constant across all the specimens. However, the pectoral fin rays, anal fin rays and scales on lateral line ranged from 13 – 14, 7 – 9 and 89 – 95, respectively (Table 4). Of all the meristic characters studied, the coefficient of variation was maximum for anal fin rays (11.46 %) followed by pectoral fin rays (3.78 %) and scales on lateral line (2.34 %). The fin formula of *S. obtusata* along the Southeastern Arabian Sea can be delineated as: D. V+I, 9; P. 13-14; V. I, 5; A. II, 7-9; C. 17; Ll. 89-95, two gill rakers on first gill arch.

Length-weight relationships (LWRs)

Three hundred and fifty two specimens encompassing of 162 males and 190 females were analyzed for studying LWR. The LWR were highly significant ($p < 0.001$) for individual sexes (males & females) and also for pooled data of both the sexes (Table 5). The values of calculated allometric coefficient '*b'* for males, females, and for combined sexes were 2.6033, 2.6815 and 2.6541, respectively (Fig. 3). The length-weight comparisons derived for males and females are $W = 0.02275\ L^{2.6033}$ and $W = 0.01786\ L^{2.6815}$, respectively. The same is determined exponentially as linearized equation: logW = -3.783330 + 2.6033logL (r^2 = 0.9566) for male and logW = -4.02500 + 2.6815logL (r^2 = 0.9696) for female. There was no significant difference ($p > 0.05$) in the mean weight of males and females (adjusted for covariate length) and between the regression slopes (*b*) of LWR. Hence, the data of both the sexes were united together and LWR was renowned as $W = 0.01945\ L^{2.6541}$ (r^2 = 0.9658, n = 352). A *t*-test conducted separately for individual sexes and also for combined sexes revealed that the slope of the regression line differed significantly ($p < 0.05$) from 3, thus representing negative allometric growth ($b < 3$) for the species (Table 5).

Relative condition factor (*Kn*)

The calculated monthly mean values of *Kn* was highest in December (1.00097 ± 0.04509) and lowest in October (1.00017 ± 0.01883) for males; while, in females the highest and lowest values were in November (1.00153 ± 0.05640) and March (1.00018 ± 0.01989), respectively (Fig. 4). The *Kn* values of females were lower in the size groups of 16 – 18 and 18 – 20 cm, moderate in 20 – 22, 24 – 26, 26 – 28 and > 28 cm and highest in 22 – 24 cm (Table 6). In

Table 4 — Statistical estimates of various meristic traits in *Sphyraena obtusata*

Meristic traits	Range (no.)	Mean	Mode	SD	SE	Coefficient of variation (%)
I dorsal spines	5	5	5	0.00	0.00	0.00
II dorsal spines	1	1	1	0.00	0.00	0.00
II dorsal rays	9	9	9	0.00	0.00	0.00
Pectoral rays	13-14	13.52	14	0.51	0.11	3.78
Ventral spines	1	1	1	0.00	0.00	0.00
Ventral rays	5	5	5	0.00	0.00	0.00
Anal spines	2	2	2	0.00	0.00	0.00
Anal rays	7-9	8.17	9	0.94	0.20	11.46
Caudal rays	17	17	17	0.00	0.00	0.00
Lateral line scales	89-95	91.61	90	2.15	0.45	2.34
Gill rakers	2	2	2	0.00	0.00	0.00

Table 5 — Length-weight relationship of *Sphyraena obtusata*

Sex	N	TL range (cm)	Weight (g)	Regression parameters					$\|t_s\|$	Growth type
				a	95 % CI of *a*	*b*	95 % CI of *b*	r^2		
Male	162	16.5-27.6	29.54-141.66	0.02275	0.01735-0.02982	2.6033	2.5167-2.6898	0.9566	9.054	A^-
Female	190	17.0-30.1	32.73-155.20	0.01786	0.01437-0.02220	2.6815	2.6131-2.7498	0.9696	9.194	A^-
Combined	352	16.5-30.1	29.54-155.20	0.01945	0.01648-0.02296	2.6541	2.6016-2.7065	0.9658	12.966	A^-

N - sample size; TL - total length; *a* - intercept of relationship; *b* - slope of relationship; CI - confidence interval; r^2 - coefficient of determination; t_s - *t*-statistic value; and A^- - negative allometric

Table 6 — Variations in the mean relative condition factor (*Kn*) of male and female *Sphyraena obtusata* in different length groups

Size group (cm)	Male		Female	
	No. of fish	*Kn* (Mean ± SD)	No. of fish	*Kn* (Mean ± SD)
16-18	02	1.00000 ± 0.00000	02	1.00000 ± 0.00000
18-20	07	1.00100 ± 0.04802	11	1.00099 ± 0.04717
20-22	38	1.00042 ± 0.02929	19	1.00140 ± 0.05437
22-24	59	1.00107 ± 0.04707	45	1.00160 ± 0.05724
24-26	49	1.00065 ± 0.03673	59	1.00120 ± 0.04981
26-28	07	1.00141 ± 0.05714	42	1.00106 ± 0.04684
> 28	-	-	12	1.00101 ± 0.04707

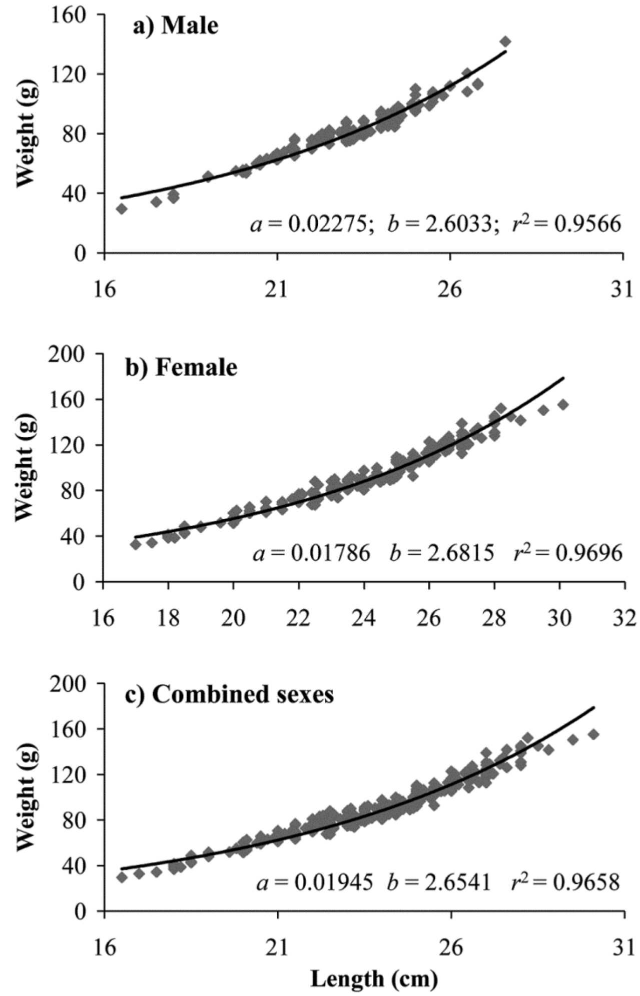

Fig. 3 — Length-weight relationship of *Sphyraena obtusata* - a) male, b) female and c) combined sexes

males, the lowest *Kn* value was observed in the size group 16 – 18 cm and the highest in 26 – 28 cm.

Discussion

Morphometric measurements of fish offer an efficient and more powerful technique for detecting differences among the groups and to differentiate between the species of similar shape[23]. The coefficient of variation observed in this study has showed wide range from a minimum of 10.22 % (PVL) to a maximum of 21.67 % (BD). Occurrence of differences within the fish populations are generally greater than 10 %[ref. 24], the high CV signifies intra-population variation. The comparison of different morphometric characters with total length showed high values of correlation (0.708 – 0.985; Table 2) indicating high degree of interdependence of these characters. Similar high values of correlation

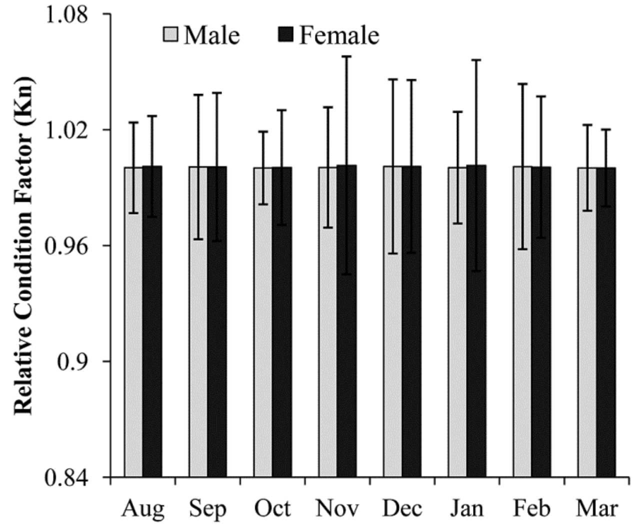

Fig. 4 — Monthly variations in the mean relative condition factor (*Kn*) of male and female *Sphyraena obtusata*

coefficient were reported from the Bombay waters for *S. obtusata*[12]. However, the highest total length of *S. obtusata* observed in this study was 301 mm, which is significantly lower than the total length (435 mm) reported from the Bombay waters[12]. The highest total length documented for Obtuse barracuda in the FishBase data is 550 mm[25]. The lower total length observed in the current investigation is might be due to heavy fishing pressure existed in the study area. Surprisingly, eight out of twelve morphometric characters recorded were in the intermediate category, indicating that these characters are not very much stable in nature from this region. Regression coefficient '*b'* value clearly indicates that all the morphometric characters showed an isometric growth in relation to the total length except for PVL (negative allometric), BD (positive allometric) and CD (positive allometric) ($p < 0.01$; Table 2). Besides allometry, the variations in the growth of *S. obtusata* was evident and found to be of taxonomic interest which will be useful for exploring intra and inter specific disparity in fish species. Morphological traits can exhibit high pliability in reply to the changes in environmental conditions for instance food prosperity and temperature[26,27].

Meristic traits are predetermined in early embryonic life stage of the entity and continue as it is thereafter[28], and the ranges for the counts were more stronger than their morphometric characters. From the present findings, it has been observed that the meristic counts continued to be constant in all size groups of fishes. Similar results were reported by Jaiswar *et al.*[12] from the Bombay waters and Karna *et al.*[29] from Odisha coast. However, fin formula given by Day[30] does not correspond strictly with the other authors and the present study. Only 1 spine on anal fin was recorded by Day[30] but in the present study 2 anal spines were accounted. Meyers[31] and Bal & Rao[32] reported 80 – 90 and 82 – 90 scales on the lateral line respectively, but in the present study 89 – 95 scales were recorded on the lateral line.

The LWR in the present study signified comparable growth patterns for males (b = 2.6033) and females (b = 2.6815) having negative allometric growth. The calculated '*b'* value of LWR was within the predicted range of 2.5 – 3.5[ref. 10]. There was no significant difference between the sexes ($p \leq 0.05$) for the covariance. On the other hand, a difference in growth rate was reported between the sexes by Premalata & Manojkumar[33] from the southwest coast of India. However, the calculated '*b'* value of LWR for combined sexes (2.6541) shows negative allometric growth in this study which is comparable with the coastal waters of Tuticorin[34] (2.3815), Bombay[12] (2.7226) and Sri Lanka[14] (2.857) but differs from Gulf of Mannar[35] (3.1318). Deviations in the '*b'* values in LWR could be due to the various factors which includes size of the sample, length range studied, territory, physiology, ontogenetic development, time of the year, population, sex, maturity stages, stomach fullness, healthiness, disease and parasite load[20,36,37], etc.

The relative condition factor indicates proper growth, feeding intensity, spawning, maturation and wellbeing of the fish[11,38]. Monthly variation in *Kn* of male and female Obtuse barracudas showed similar values around 1, which indicates almost identical 'condition' for both the sexes. The growth condition of the fish worked out to be good when the value of *Kn* is greater than 1, while < 1 indicates unhealthy condition of fish[11]. The *Kn* values of *S. obtusata* caught along the southeastern Arabian Sea, indicates good health status of the both sexes. The variation in *Kn* values of females was quite trivial, having lower values during the pre-monsoon months (February-March) and slightly higher values during November and January. In general, the lower *Kn* values were recorded during the spawning period due to the utilization of energy for reproductive activity and the higher *Kn* values during the post spawning period with enhanced feeding activity to recover from the spawning stress[39]. Further, the monthly *Kn* of fish is affected by the seasonal variations in environmental conditions, dietary habits, existence of food and swimming behavior of the fish[10,40,41]. The near integrity in *Kn* among the size groups may also be due to its protracted spawning habit or factors other than the spawning[42]. The highest *Kn* values observed in the size group of 22 - 24 cm in female fish may be attributed to the maturation and spawning activity[43] as the estimated length at first maturity (Lm_{50}) of this species is 21.3 cm[44].

The results of this study might be helpful as guideline instructions for future biological and population based investigations. The morphometric and mereistic details of the current study could be used for the similar taxonomic works. The established LWR can be useful in estimating the mean weight for a specified length group, and conversion of length measurements into body mass whenever, measurement of both length and body weight of each specimen is practically cumbersome in the field based studies or on-board research crafts.

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Conflict of Interest

The authors declare that they have no competing or conflict of interest.

Author Contributions

MMM & NKS: Collection of data, formal analysis and investigation; MR: Conceptualization, supervision, resources and writing - original draft; and KMR: Data analysis, writing - review & editing.

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