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Biometric analysis of the flat needlefish *Ablennes hians* (Valenciennes, 1846) (Pisces: Belonidae) in the south-eastern Arabian Sea

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The study was aimed to investigate the relationship between various morphometric measurements and meristic counts and to establish the length-weight relationships (LWRs) and length-length relationships (LLRs) of flat needlefish *Ablennes hians* (Valenciennes, 1846) that were collected from longline fisheries in the south-eastern Arabian Sea between October 2015 and August 2017. Twenty-two morphometric measurements and four meristic counts of 173 specimens were examined for biometric analysis, and 350 specimens (45-122 cm TL, 90-2585 g TW) were analyzed for studying LWRs. Morphometric variables showed a significant correlation between the variables with the highest observed correlation between SL, FL and TL (r > 0.99). The descriptive statistics for all the meristic counts were found within the range provided by the earlier authors. A differential relative growth was observed across morphometric characters. Strong positive allometry was recorded for pectoral fin length, the height of dorsal and anal fin and pre-ventral length, whereas pronounced negative allometry was evident in case of morphometric variables from the head region. The LWRs showed similar growth pattern for male (b = 3.447) and female (b = 3.299) individuals. Therefore, the LWR was expressed for pooled data as $W = 0.000321L^{3.312}$ (R^2 = 0.929, p < 0.001).

[**Keywords:** Length-length relationships; Length-weight relationships; Morphometric; Meristic; South-west coast]

Introduction

Morphometric and meristic characters are one of the easiest and frequently used methods for identification of species called morphological systematics[1]. The morphometric relationships between various body parts of fish are also used to assess the well-being of individuals and to determine possible differences between separate unit stocks of the same species[2]. Moreover, phenotypic markers are more suitable to study short-term, environmentally induced variation, which is perhaps most suitable for fisheries management[3]. Relationships between different types of lengths termed as length-length relationships (LLRs) are useful to convert several measures of body length[4,5]. Among them, total length (TL) – standard length (SL) relationship (LLR) is important for comparative growth studies, which is more applicable to estimate total length where only standard length is known[6]. In fishery science, length-weight relationships (LWRs) are generally used to estimate the average weight for a given length group and to convert length measurement into weight to give the estimate of biomass and yield, where technical difficulty is found in weighing the fishes[7,8]. The LWRs are also used as an important tool for biometric and morphological comparisons between different species in the same taxon and populations from different geographical area[9,10,11,12,13]. Thus, LWRs are important components of fisheries biology and an accurate estimate can be highly useful for fisheries management[8].

Needlefishes (family Belonidae) comprised 34 valid species in 10 genera all over the world[14]. The genus *Strongylura* with 14 species and *Tylosurus* with 6 species are among the two most diverse genera of the family. The needlefishes though mostly marine, 12 species are found in fresh waters and several species of *Strongylura* are reported to migrate a long distance into the freshwater area[14]. Being a pelagic group, needlefishes are found at the surface of the water. They are carnivorous in nature, mostly feed on small fishes captured by their beaks in a sideways fashion[15].

In India, the family has 9 species under 5 genera: One species each in *Ablennes*, *Xenentodon*, *Platybelone* and three each in *Strongylura* and *Tylosurus*[16]. Needlefishes are locally called as kolan along Kerala coast and have five representatives, namely, *Ablennes hians*, *Tylosurus crocodilus crocodilus*, *T. acus melanotus*, *Strongylura leiura* and *S. strongylura.* Among the five species, *A. hians, T. crocodilus crocodilus* and *T. acus melanotus* are targeted by the long liners (outboard fibre boat: OAL 7-10 m, engine horsepower 6-9.9 HP) along the coast. *A. hians* and *T. crocodilus crocodilus* form a regular fishery, whereas *T. acus melanotus* constitute a minor fishery due to occasional landing. *S. leiura* and *S. strongylura* landed rarely by ring seine units as bycatch along with other pelagic fishes. Flat needlefish, *A. hians* is a marine, reef-associated species found both in neritic and oceanic waters, mostly aggregated near islands at a depth of 3 m from the surface of water[16]. The fishes are having a very good demand both in local and distant markets due to its good meat quality and excellent flavor. Even though few studies have conducted on *A. hians*[17,18,19,20], currently the information on morphological characters of this species from Indian waters, as well as in general is lacking. The main goal of this study was to investigate the relationships that exist between various morphometric measurements and meristic counts and to establish LWRs and LLRs for the species collected from Kerala waters in India.

Materials and Methods

Specimens were collected on a weekly basis between October 2015 and August 2017 from three Fisheries Harbours along the Kerala waters, south-west coast of India: Cochin Fisheries Harbour (Lat. $09^0 56'327''$N, Long. $76^0 15'764''$E), Munambam Fisheries Harbour (Lat. $10^0 10'965''$N, Long. $76^0 10'258''$E), and Kalamukku (Lat. $09^0 59'924''$N, Long. $76^0 14'564''$E). Fishes were captured by long lines with serially arranged 150-200 hooks (hook no. IX-XIV) and small square thermocol floats. Specimens without physical damage were brought to the laboratory in iced condition for further studies and identified based on the standard key given by Collette[15]. All the morphometric measurements and meristic counts were recorded according to Hubbs and Lagler[20]. The morphometric measurements were measured using a digital Vernier calliper with 0.1 cm accuracy and measurements over 300 mm were taken using fish measuring board and scale. Total body weight (TW) was determined by an electronic weighing balance with 0.1 g accuracy for each species. Twenty-two morphometric measurements were analysed: TL, SL, fork length (FL), head length (HL), pre-dorsal length (PDL), pre-pectoral length (PPL), pre-ventral length (PVL), pre-anal length (PAL), ventral-to-anal length (VAL), caudal length (CL), caudal width (CW), pectoral length (PL), ventral length (VL), dorsal height (DH), anal height (AH), depth at dorsal origin (DD), depth at ventral origin (DV), head depth (HD), pre-orbital length (POL), eye diameter (ED), snout length (SnL), and inter-orbital width (IOW). Four meristic counts were also taken for analysis: Number of rays in dorsal fin (DF), pectoral fin (PF), ventral fin (VF), and anal fin (AF). Pearson correlation matrix for all morphometric variables was generated to see the nature of the relationship between them. Nineteen morphometric variables were scaled to standard length and subjected to descriptive statistics such as minimum, maximum, arithmetic mean, standard deviation, and coefficient of variation. Descriptive statistics for meristic characters include median, mode, the frequency of mode, minimum, maximum, and coefficient of variation. The significant differences in morphometric characters of male and female individuals were analyzed using t-test. Pairwise linear regression of log-transformed morphometric variables with log-transformed standard length and head length was also carried out and regression coefficient was assessed for an underlying allometric pattern of the variables under study. Growth gradients against an overall measure of size based of the allometric coefficient ($PC1*P^{0.5}$, where P is the number of variables) extracted from PC1 of the covariance matrix of 20 log-transformed variables is constructed to visualize differential growth among morphometric variables[21,22,23]. The LWRs were calculated for males, females and pooled individuals separately using the equation, $TW = aTL^b$ given by Le Cren[24], where TW is the total body weight (g) and TL is the total length (cm), a is an intercept related to body form, and b is the coefficient indicating allometric growth. The parameters, *a* and *b* were estimated from the logarithmically transformed equation, $log\ TW = log\ (a) + b\ log\ (TL)$ (Froese, 2006). The 95% confidence limits (*Cl*) of parameters *a* and *b* and co-efficient of determination (R^2) were estimated. Analysis of covariance (ANCOVA) was employed to test the difference in mean log-weight adjusted for the covariate (log-length) and to test the homogeneity (equality) of regression slopes between male and female individuals at 1% and 5% level of significance. A student t-test was performed to test the difference between calculated b value against the null hypothesis of isometric growth (H_0: b=3) at 1% and 5% level of significance. All the statistical analysis was carried out using MS-Excel and PAST 3.0.

Results

Morphometric and meristic

In this study, a total of 173 specimens of *A. hians* were examined for morphometric and meristic examination. Several morphometric ratios showed significant difference across males and females at 5 % level of significance and hence descriptive statistics were separately tabulated for them. Descriptive statistics of 19 morphometric ratios indicated maximum coefficients of variation (CV) for DH/SL (CV = 14.29 % for males, 14.05 % for females), whereas the lowest was noted in the case of PPL/SL (CV = 1.79 % for males, 1.63 % for females) and PAL/SL (CV = 1.74 % for males, 1.47 % for females) (Table 1). A Pearson correlation matrix for 22 morphometric variables showed a significant correlation between the variables with the highest observed correlation between SL, FL and TL (r > 0.99). HL was found to be highly correlated with TL, FL, SL (r > 0.90) and the least correlated with CL (r=0.77) and DH (r = 0.78). POL, SnL and CL were found the least correlated with other morphometric variables.

Descriptive statistics for four meristic characters indicated the highest variation in case of pectoral fin rays (CV = 4.01 %) followed by dorsal fin rays (CV = 3.62 %) and anal fin rays (CV = 3.32 %), whereas ventral fin rays (6) remained constant across all the specimens (Table 2).

Length-length relationships

The LLRs by pair-wise linear regression of log-transformed morphometric measurements (Y variable) against the log-transformed SL (X variable) showed a regression coefficient b value of near unity for TL, FL, PDL, PVL, PAL, VAL, CW, DV, clearly indicating the isometric growth of these variables in relation to standard length, whereas a lower value of b was observed for HL (0.762) and PPL (0.795) and CL (0.847) revealing negative allometric growth. Similarly, higher value of b was observed for PL (1.490), VL (1.349), DH (1.510), AH (1.498), and DD (1.202), showing positive allometry with SL (Table 3). Likewise, log-transformed measurements of head region (Y variable) when regressed against

Table 2. — Descriptive statistics for meristic counts of *Ablenneshians*in the south-eastern Arabian Sea

Meristic	N	Median	Mode	Freq. of mode	Range	
					Min.	Max.
PF	173	14	14	117	13	15
VF	173	6	6	173	6	6
AF	173	25	26	75	23	27
DF	173	24	24	110	21	26

Table 1 — Descriptive statistics for morphometric ratios of *Ablenneshians*in the south-eastern Arabian Sea during the period from October 2015 to August 2017

Ratios	Male			Female		
	N	Mean ± SD	Range	N	Mean ± SD	Range
HL/SL	91	0.267± 0.014	0.234-0.309	82	0.257 ± 0.016	0.223-0.291
PDL/SL	91	0.765 ± 0.014	0.740-0.861	82	0.768 ± 0.013	0.727-0.794
PPL/SL	91	0.276 ± 0.016	0.231-0.311	82	0.266 ±0.017	0.231-0.303
PVL/SL	91	0.568 ± 0.014	0.545-0.644	82	0.574 ± 0.018	0.531-0.657
PAL/SL	91	0.745 ± 0.013	0.722-0.830	82	0.750 ± 0.011	0.720-0.780
VAL/SL	91	0.178 ± 0.008	0.161-0.195	82	0.177 ± 0.010	0.156-0.199
CL/SL	91	0.112 ± 0.009	0.090-0.129	82	0.108 ± 0.009	0.086-0.129
CW/SL	91	0.019 ± 0.001	0.016-0.022	82	0.018 ± 0.001	0.015-0.022
PL/SL	91	0.111 ± 0.014	0.072-0.139	82	0.103 ± 0.012	0.069-0.134
VL/SL	91	0.068 ± 0.007	0.049-0.084	82	0.066 ± 0.005	0.049-0.083
DH/SL	91	0.095 ± 0.014	0.068-0.129	82	0.092 ± 0.013	0.062-0.129
AH/SL	91	0.109 ± 0.015	0.076-0.142	82	0.105 ± 0.013	0.075-0.144
DD/SL	91	0.080 ± 0.006	0.065-0.092	82	0.077 ± 0.005	0.066-0.088
DV/SL	91	0.079 ± 0.006	0.065-0.092	82	0.074 ± 0.006	0.064-0.091
HD/HL	91	0.253 ± 0.023	0.206-0.303	82	0.253 ± 0.023	0.195-0.297
POL/HL	91	0.667 ± 0.028	0.586-0.773	82	0.663 ± 0.032	0.525-0.805
ED/HL	91	0.095 ± 0.007	0.076-0.117	82	0.094 ± 0.006	0.079-0.106
SnL/HL	91	0.703 ± 0.026	0.533-0.740	82	0.705 ± 0.031	0.526-0.847
IOW/HL	91	0.121 ± 0.011	0.101-0.159	82	0.121 ± 0.010	0.092-0.147

the log-transformed HL (X variable) showed a regression coefficient *b* value of near unity for POL, ED, and SnL indicative of isometric growth in relation to HL, whereas for HD (1.241), and IOW (1.224) it was found higher than unity, a case of positive allometry (Table 3). Defining allometry in relation to a particular morphometric character does not always give the right picture. Hence, a growth gradient based on the allometric coefficient against the overall measure of size extracted from PC 1 of the covariance matrix of log-transformed variables were also constructed. Strong positive allometry was recorded for PL, VL, DH and AH, whereas pronounced negative allometry was evident in the case of morphometric variables from the head region (Fig. 1). The results for both the approach are concurrent affirming SL as a general measure overall growth in size.

Table 3 — Length–length relationships (LLRs) for *Ablenneshians* from the south-eastern Arabian Sea

Equation	Regression parameters a	Regression parameters b	95% Cl of *a*	95% Cl of *b*	r^2
LogTL = a + b × LogSL	0.065	0.984	0.043 to 0.087	0.973 to 0.996	0.994
LogFL = a + b × LogSL	0.039	0.988	-0.001 to 0.079	0.967 to 1.009	0.980
LogHL = a + b × LogSL	-0.134	0.762	-0.229 to -0.038	0.712 to 0.813	0.837
LogPDL = a + b × LogSL	-0.122	1.004	-0.155 to -0.089	0.986 to 1.021	0.987
LogPPL = a + b × LogSL	-0.181	0.795	-0.287 to -0.075	0.739 to 0.851	0.821
LogPVL = a + b × LogSL	-0.210	0.982	-0.264 to -0.156	0.954 to 1.011	0.964
LogPAL = a + b × LogSL	-0.128	1.001	-0.159 to -0.097	0.984 to 1.017	0.988
LogVAL = a + b × LogSL	-0.951	1.106	-01.039 to -0.863	1.059 to 1.152	0.927
LogCL = a + b × LogSL	-0.671	0.847	-0.834 to -0.508	0.760 to 0.933	0.685
LogCW = a + b × LogSL	-1.694	0.980	-1.834 to -1.554	0.906 to 1.054	0.798
LogPL = a + b × LogSL	-1.898	1.490	-2.107 to -1.689	1.379 to 1.600	0.804
LogVL = a + b × LogSL	-1.834	1.349	-1.984 to -1.683	1.269 to 1.428	0.866
LogDH = a + b × LogSL	-1.995	1.510	-2.230 to -1.761	1.386 to 1.634	0.770
LogAH = a + b × LogSL	-1.913	1.498	-2.124 to -1.703	1.387 to 1.610	0.803
LogDD = a + b × LogSL	-1.487	1.202	-1.610 to -1.364	1.137 to 1.267	0.885
LogDV = a + b × LogSL	-1.317	1.107	-1.466 to -1.169	1.028 to 1.185	0.818
LogHD = a + b × LogHL	-0.913	1.241	-1.050 to -0.776	1.136 to 1.346	0.760
LogPOL = a + b × LogHL	-0.140	0.971	-0.212 to -0.068	0.916 to 1.026	0.876
LogED = a + b × LogHL	-0.937	0.933	-1.049 t0 -0.826	0.848 to 1.019	0.731
LogSnL = a + b × LogHL	-0.196	1.033	-0.264 to -0.128	0.981 to 1.085	0.899
LogIOW = a + b × LogHL	-1.212	1.224	-1.344 to -1.080	1.123 to 1.325	0.769

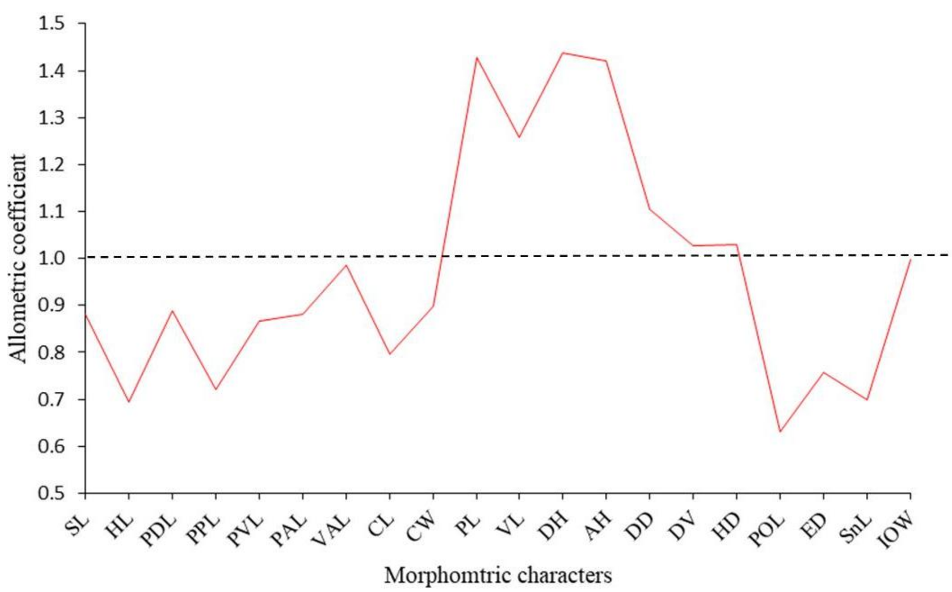

Fig. 1.— The allometric coefficient for morphometric variables of Ablennes hians in the south-eastern Arabian Sea

Length-weight relationships

Altogether 350 specimens in size range (45-122 cm TL, 90-2585 g TW) were analyzed for studying LWRs of *A. hians* collected from Kerala waters, south-west coast of India. Information on sample size, total length range (cm) and body weight range (g), LWRs parameters with 95% *CI* of *a* and *b*, and coefficient of determination (R^2) for males, females and pooled individuals are given in Table 4. All the LWRs were highly significant ($p < .001$, $R^2 > 0.930$). The estimated *b* values in LWRs for males, females and pooled data were 3.447, 3.299 and 3.312, respectively. The ANCOVA for log-transformed length and weight variables indicated a significant difference ($p < 0.01$) in mean weight of males and females (adjusted for covariate standard length), whereas no significant differences ($p > 0.05$) between the slopes (*b*) of length-weight relationships (LWRs) were observed (Table 5). Therefore, LWR was expressed for pooled data as $W = 0.000321L^{3.312}$ ($R^2 = 0.929$, $n = 350$) (Fig. 2). The slope of the regression line was significantly different from 3.00 (*t* statistics = 6.42), thus indicating positive allometric growth for the species.

Discussion

The morphometric characters for the species showed a very narrow range as the recorded highest CV was only 14.29% of DH/SL, whereas in most of the cases it is around or lower than 5%. Nevertheless, a significant statistical difference was evident across sexes which prompted a differential tabulation of the results for facilitating future comparisons from different locations. As the resource is mostly caught by hook and line, a size-selective gear (hook size), the catches were skewed towards larger size class. Hence, the representation of lower size class in the current study was sub-optimal which could possibly be attributed towards the realized narrow ranges for the descriptive statistics estimates, as major ontogenic shifts in morphometric characters might have gone unaccounted. As the estimates were based on samples from commercial catches, the skewed length composition was an inherent constraint of the study. The descriptive statistics for all the meristic counts were found within the range provided by the earlier authors[25,26,15,] with slightly broader range for the dorsal fin rays (Table 6). As the meristic characters get fixed at the time of metamorphosis from larvae to juveniles[28], the ranges for the counts were more robust than their morphometric counterparts.

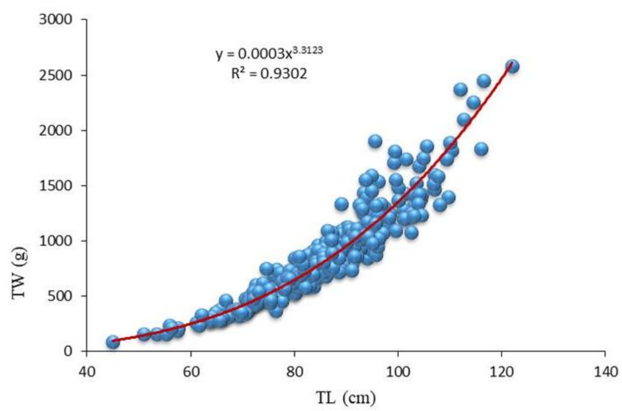

Fig. 2 — Length-weight relationship (LWR) of Ablennes hians (pooled) in the south-eastern Arabian Sea

Table 4 — Descriptive statistics and estimated Length-weight relationships (LWRs) parameters of *Ablenneshians*in the south-eastern Arabian Sea during the period from October 2015 to August 2017

Sex	N	Total length range (cm)	Weight range (g)	a	95% CI a	b	95% CI b	r2
Male	181	53.5-114.5	155-2255	0.000184	0.000101-0.000336	3.447	3.310-3.584	0.932
Female	167	45-122	90-2585	0.000327	0.000184-0.000579	3.299	3.171-3.428	0.939
Pooled	350	45-122	90-2585	0.000321	0.000210-0.000490	3.312	3.217-3.408	0.930

N, number of specimens studied; *a*, intercept of relationship; *b*, slope of relationship; CI, confidence interval; r^2, coefficient of determination.

Table 5 — Results of ANCOVA for Length-weight relationships (LWRs) of males and females of *Ablenneshians*in the south-eastern Arabian Sea

	Test for equal means, adjusted for covariate				
	Sum of sqrs	df	Mean square	F	P(same)
Adj. mean:	0.103404	1	0.103404	33.05	<0.001
Adj.error:	1.08565	347	0.003129		
Adj.total:	1.18905	348			
	Test for homogeneity (equality) of slopes				
F:	2.396				
P (same)	0.1225 (>0.01 shows equality of slopes)				

Table 6 — Comparison of meristic counts of the present study with earlier reports of*Ablenneshians*

Meristic counts	Jones &Kumaran (1980)	Collette, 1984	Talwar&Kacker, 1984	Collette, 1986	Present study
DF	21	23-26	23-27	22-25	21-26
AF	23	23-27	25-28	25-27	23-27
PF	13	13-15	-	13-15	13-15
VF	5	-	-	-	5

Length-length relationships by pair-wise linear regression of log-transformed morphometric measurements against the log-transformed SL showed high R^2 value except for CL, CW, DH and HD ($R^2 < 0.685$). Regression coefficient *b* value of near unity for TL, FL, PDL, PVL, PAL, VAL, CW, and DV clearly indicating the isometric growth of these variables in relation to SL. HL ($b = 0.762$) and PPL ($b = 0.795$) and CL ($b = 0.847$) showed negative allometric growth in relation with SL. Negative allometric growth of HL is quite obvious in several groups of fishes and the rate of change in HL slows down as the fish grows bigger in length with age[29]. Higher value of *b* was observed for PL (1.490), VL (1.349), DH (1.510), AH (1.498), DD (1.202), showing positive allometry with standard length as all the fin lengths become more elongated and depth at dorsal origin increases more as it grows to accommodate gonads post-maturation. A PC 1 based estimation of allometric coefficient against an overall measure of size revealed a similar pattern as estimated by pair-wise regression against SL, showing a fair use of SL as indicative of overall growth of fish. SL has been widely used across several species and groups of fishes as a reference measurement for a general comparison of growth.

Length-weight relationships showed similar growth pattern for males (b = 3.447) and females (b = 3.299). The value of LWRs parameter *b* was usually found within the expected range of 2.5-3.5[7]. In the present study, *b* values for all the cases remained within this expected range and greater than 3, indicating hyperallometric growth pattern. The growth of a fish is hyperallometric when $b > 3$, a fish increases more in weight than predicted by its increase in length i.e. it becomes less elongated or more round as it grows; also termed as positive allometric[8]. The high values of the coefficient of determination ($R^2 > 0.9$) for all the cases describe the reliable estimates of LWRs. Earlier reports on the LWRs were restricted to pooled data from South Africa by Torres (1991) with estimated *b* value as 3.130 and maximum length covered: 100 cm FL and from Gulf of Mannar by Mohamad Kasim *et al*[19] with $b = 3.323$ and length range: 44-93.4 cm FL, which was also found to be in agreement with the present study. There were some variations in *b* values estimated in the present study in comparison with the earlier estimates which can be attributed due to several factors, such as sample size, length range covered, type of habitat, ontogenetic development, season, population, sex, gonad maturity, diet, and health[30&31]. Moreover, this study provides a new estimate for *A. hians* using wider size range data (45-122 cm TL) covering all the seasons.

Conclusion

In conclusion, the result of this study: Morphometry, meristic, LLRs and LWRs analysis could be useful as baseline information for subsequent biological and population-based studies. Morphometry and meristic data of this study can be used for the comparative taxonomic study. In many cases, owing to its large size it is difficult to measure the weight of the fish in the field. Thus, the established LWRs can be used to estimate the weight of the fish from the known length. It can also find application in yield and biomass estimation, and comparative growth studies of the species between different habitats, which is required for fishery conservation and management plan. The LLRs are used to convert length measurements from one length type into another for comparative growth studies apart from exploring allometric gradients across different levels.

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