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Length-weight relationship and condition factor of four poorly known deep-sea demersal finfishes from Indian EEZ

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Length-Weight Relationships (LWRs) and condition factor (K) were estimated for four deep-sea fish species belonging to four families from the Southeastern Arabian Sea and Western Bay of Bengal of the Indian Exclusive Economic Zone (EEZ). The specimens of *Lamprogrammus brunswigi* (Ophidiidae), *Alepocephalus blanfordii* (Alepocephaliformes), *Parascombrops pellucidus* (Synagropidae) and *Pterigotrigla hemisticta* (Triglidae) were collected using a high-speed demersal trawl II (HSDT II, crustacean version) and an EXPO-model trawl onboard FORV *Sagar Sampada* during March 2020. The *b* values ranged from 2.97 to 3.34 and the coefficient of variation (r^2) ranged from 0.92 to 0.95. *P. hemisticta* showed negative allometric growth, and the remaining three species showed positive allometric growth. The condition factor was found to be high for *P. hemisticta* (1.108) compared to *P. pellucidus* (0.453), *A. blanfordii* (0.257), and *L. brunswigi* (0.082).

[**Keywords**: Condition factor, Deep-sea fishes, Indian EEZ, Length-weight relationship]

Introduction

The Indian EEZ comprising the Arabian Sea and Bay of Bengal waters is rich in fishery resources with high species diversity and endemicity[1-3]. Estimation and understanding of the bionomics of deep-sea fishes beyond 200 m in the Indian EEZ is still challenging due to several reasons, mainly technical and logistic constraints. The Length-Weight Relationships (LWRs) values and condition factor (K) are important baseline information for the management and conservation of fishery resources[4]. LWRs are used to evaluate the weight corresponding to a given length, and condition factors to assess the well-being of the fish[5]. Despite the fact that estimating LWR is a recurrent research work for fisheries professionals[4], such data on deep-sea fishes in Indian waters are scanty compared to inshore and coastal species[2,3,6]. Deep-sea fishes occupy about 75 % of the biosphere, and play an important role in deep-sea food webs[7]. Deep-sea fishes have distinct life-history characteristics such as slow growth, long life, late maturation, low fecundity, and irregular recruitment with those of the neritic zone, all of which are caused by extreme environmental conditions in deeper sea or ocean areas and are reflected in their feeding and reproductive biological traits[8]. Though it is hard to give a complete picture of the population structure and dynamics of these fishes, snapshot data from biological studies will provide valuable information on their basic biological characteristics such as food and feeding, condition indices, and reproductive biology[9]. Among these, data on LWRs is very essential for the assessment of fishery resources as it can be used to estimate the weight-at-age from length-in-yield assessments[10,11] and to compare the intra and inter-species variations in the growth rate[12]. Even though Indian waters are well known for deep-sea fishery resources, our understanding of the major life-history characteristics of these resources is very limited[13]. The deep-sea fishes selected for the present study are the major species caught during the deep-sea exploratory surveys at a depth range of 200 – 1000 m[(refs. 2,14)]. However, no information is available on the LWR of these species except for *P. hemisticta*. The growth parameters provided during the present study would help to improve understanding of the growth characteristics of poorly known deep-sea fishes.

Materials and Methods

The samples were collected as part of the exploratory deep-sea bottom trawling operations onboard FORV *Sagar Sampada* of the Centre for Marine Living Resources and Ecology (CMLRE), (Cruise No. 398) in the Southeastern Arabian Sea (8° N Lat and 76° E Long) and Western Bay of Bengal (10° N to 17° N Lat and 80° E to 83° E Long (Fig. 1) using a high-speed demersal trawl II (HSDT-CV) at a depth range of 200 – 1000 m during March 2020. The basic information including depth of operation, trawling duration, meristic and morphometric measurements were recorded onboard and the fishes were identified up to species level following standard identification keys[15-18]. Total Length (TL) was measured to the nearest millimeter and Weight (W) was recorded to the nearest milligram. Data were log-transformed for identifying and removing outlier values from further statistical analysis[4,19]. The LWRs were calculated using the regression equation $W = aL^{b}$(ref. 4) and transformed into its logarithmic form: $\log W = \log a + b \log TL$, where, W is the total weight (g), TL = total length (cm), and *a* and *b* are the regression parameters. R^2 thus obtained indicated the robustness of the sample considered. The 95 % confidence limit was also estimated to understand the spread of the growth parameters (*a* and *b*) among each species[20]. Statistical analyses were carried out using Microsoft Excel 2010. Fulton's Condition factor (K) was determined using the formula $K = 100\ W/L^{3}$(ref. 21), where W is the weight of the fish and L is the length of the fish.

Results and Discussion

LWRs for all four species in the present study were highly significant, with $p < 0.001$. The detailed information on species name, sample size (N), ranges of total length (cm), body weight (g), growth parameters *a* and *b*, 95 % CL of *a* and *b*, and coefficient of determination, r^2 are given in Table 1. The scatter diagram of LWRs of species studied is shown in Figure 2. The highest and lowest *b* values were recorded for *P. pellucidus* (3.34) and *P. hemisticta* (2.97), respectively. The coefficient of determination (r^2) was found to be higher than 0.9 for all the species, and the highest values were recorded for *L. brunswigi* (0.95), followed by *P. hemisticta* (0.93), *A. blanfordi* and *P. pellucidus* (0.92), respectively. The relationship between length and weight of fish species varies based on several factors such as maturity, season, depth of capture, area, sex, length class, food and feeding, sample size, gear selectivity and fluctuations in hydrographical features[4,22,23].

All four species (*Lamprogrammus brunswigi*, *Alepocephalus blanfordii*, *Parascombrops pellucidus* and *Pterigotrigla hemisticta*) examined validate the expected values of the allometric coefficient *b i.e.* 2.5 – 3.5 as coined by Froese[4]. The *b* value estimates of

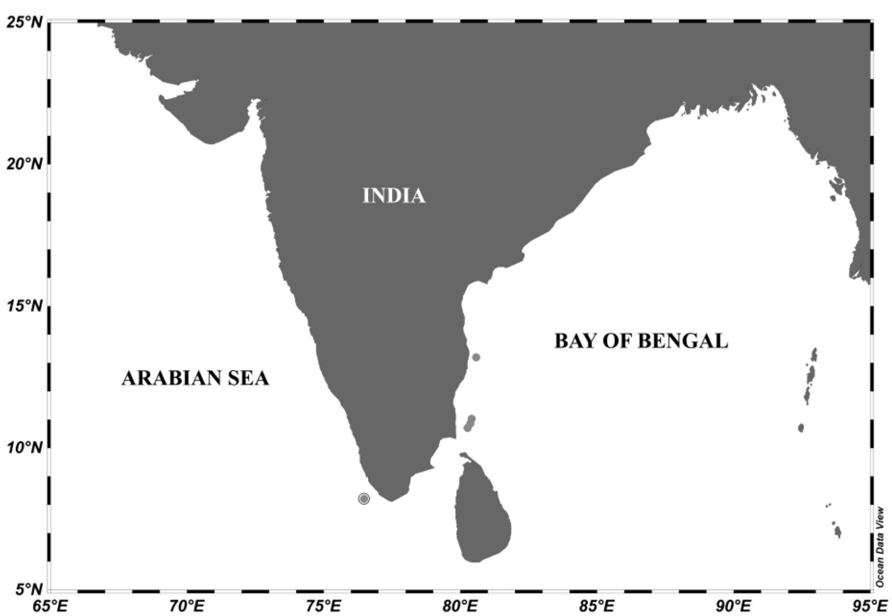

Fig. 1 — Map showing study area

Table 1 — Descriptive statistics and estimated length-weight relationship parameters of four deep-sea fish species collected from Southeastern Arabian Sea and Western Bay of Bengal of Indian EEZ

species	N	Total length (cm)		Total weight (g)		Regression parameters				
		Min	Max	Min	Max	*a*	*b*	95 % CL of *a*	95 % CL of *b*	r^2
Lamprogrammus brunswigi (Brauer, 1906)	48	32.8	66.7	99	1237	0.0009	3.33	0.0003-0.0022	3.100-3.551	0.95
Alepocephalus blanfordii Alcock, 1892	21	30.5	47.8	176	907	0.0025	3.26	0.0004-0.0153	2.782-3.747	0.92
Parascombrops pellucidus Alcock, 1889	338	6	9.8	1.835	10.454	0.0045	3.34	0.0037-0.0055	3.237-3.436	0.92
Pterigotrigla hemisticta (Temminck and Schlegel, 1843)	51	13	21.1	18	93	0.011	2.97	0.003-0.016	2.743-3.200	0.93

Abbreviations: Min - minimum; Max - maximum; *a* - intercept; *b* - slope; CL - confidence limits; N - total number of samples; r^2 - coefficient of determination

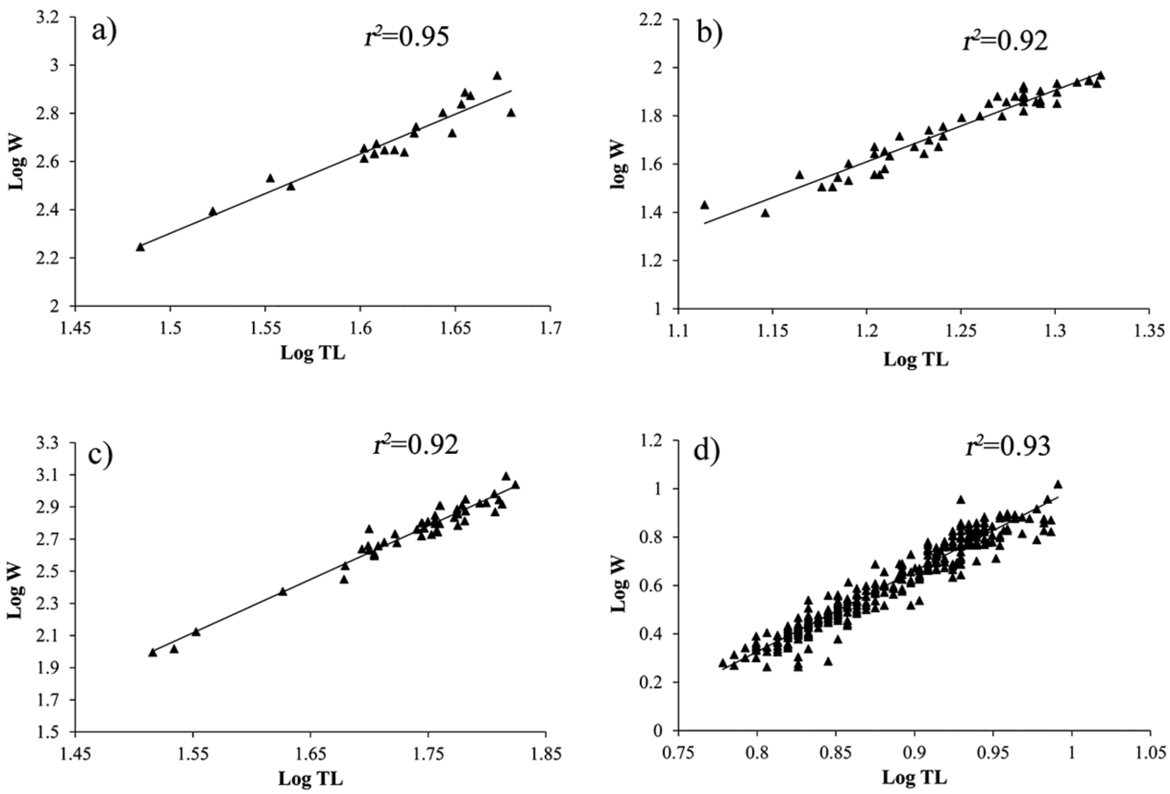

Fig. 2 — Scatter plot of LWRs of (a) *L. brunswigi*, (b) *A. blanfordii*, (c) *P. pellucidus* and (d) *P. hemisticta*

Lamprogrammus brunswigi (3.33), *Alepocephalus blanfordii* (3.26), *Parascombrops pellucidus* (3.34) were high and exhibited a positive allometric growth (> 3) confirmed by *t*-test ($p < 0.05$)[24]. No previous estimations are available for three species except *P. hemisticta* which restricts the comparison and validation of *b* values. However, the length-weight parameter *b* estimated for *Synagrops japonicus* (*b* = 2.86) and *Acropoma japonicum* (*b* = 3.02), a sister genus is comparable with our estimates *of Parascombrops pellucidus* (3.34)[8]. The *b* value was comparatively high for *Parascombrops pellucidus* with the other two species. A larger sample size (338) in the present study could be a reason for these observed differences, along with marked variations in the oceanographic characteristics of the region. Furthermore, various biotic and abiotic factors were not included in this study, and their influence on the *b* values cannot be ignored[25,26]. The *b* value estimated for *A. blanfordii* is in accordance with the *b* value of its congener species *Alepocephalus bicolor*[22]. However, these results are in conflict with the finding of Deepu *et al.*[27] where a very low *b* value (1.28) in samples collected from southwest coast of India was reported. This could be due to variations in the samples considered including size, population differences, or the heterogeneity of the habitat conditions[28]. Interestingly, the *b* values estimated for *Lamprogrammus brunswigi* (3.35) are very close to the value reported for its congener species *Lamprogrammus niger*[29]. Moreover, LWRs of *L. brunswigi* were within in the range of estimations based on Bayesian models of FishBase. *P. hemisticta* (2.97) has exhibited negative allometric growth with *b* value of 2.97 in the study. The LWRs of this species previously reported from India is 3.156 (unsexed)[3], which is higher than our findings. These small disparities could be attributed to sample collection bias and a relatively small sample range[30]. The value of parameter *b* presented in the current study is within the predicted range for all four species, and thus it may be efficiently utilized to predict weight from the length range provided. The findings are further supported by Wang *et al.*[31], who proposed that for the estimation of weight from length using LWRs parameters, the length should be strictly confined to the length ranges used in the linear regression.

The condition factor (K) is a significant metric for evaluating the intensity of feeding, age, and growth rates in fish[32]. Since there was no significant variation in K value between male and female individuals of each species, pooled data were taken into account for the study. Good relative K values were noticed in *P. hemisticta* (1.108) followed by *P. pellucidus* (0.453), *A. blanfordii* (0.257) and *L. brunswigi* (0.082) (Fig. 3). Excellent growth conditions in fish are reflected when the K value approaches one or is greater than one[33]. Since K value is substantially impacted by both biotic and abiotic environmental variables, it's being used as a measure to assess the integrity of the aquatic ecosystem in which fish inhabit[34]. Most fish in the present study showed poor condition, except *P. hemisticta*. But these findings conflict with those of Aura *et al.*[35], who stated deep-sea fish from the Western Indian Ocean show good condition as the K value was higher than 1 for all nine species considered in the study. According to Gayanilo & Pauly[36], certain elements such as sex, stages of maturation, stomach condition, growth rate

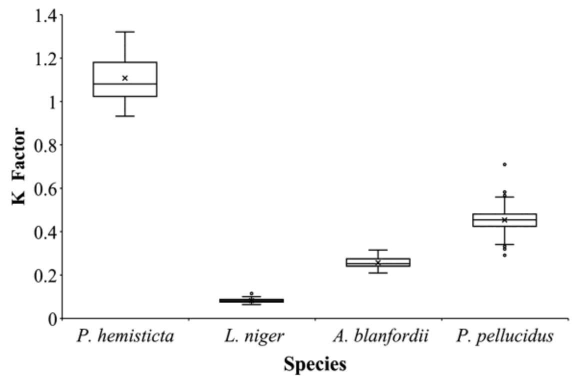

Fig. 3 — Condition factor (K-value) of different fish species in the study

differential between males and females, and area of distribution frequently affect the well-being of a fish, which could be a major reason for the contrariety with previous reports. In this study, the distribution of *P. hemisticta* was limited to 200 to 250 m. With increasing depth, organisms appear to be more vulnerable to a drop in food supply[37]. Since food availability is an important aspect influencing the condition factor[26,38], shallow areas are exhibited by affluent food resources by means of surface photosynthesis and organic matter derived from the euphotic zone, which may be attributed to the high condition factor of *P. hemisticta*. The other three species were found between 300 and 1000 m in depth. The deep-sea ecosystem beyond 300 m depth is pervaded by low temperatures and scarce availability of preferred food items[37]. These extrinsic factors could be a major reason for the low growth[39] and well-being of the remaining three fishes. The two important elements defining the condition factor of fishes are sexual dimorphism and seasonal variation[40]. Studies by Barnham & Baxter[41], delineate that the condition factor falls drastically in females due to less feeding and enormous energy loss at the time of reproduction and spawning. However, earlier findings of Masoomizadeh *et al.*[40] depict that males had a higher condition factor than females in the spring, autumn, and winter, whereas females had a higher condition factor in the summer. During these seasons, males were observed to feed more intensely than females, whereas the increase in female gonad volume in summer was most likely the cause of a surge in female condition factor when compared to male fishes[42]. This study did not address the condition factor of fishes with respect to their sexual dimorphism and seasonal disparities. This has to be substantiated with more species and sampling period.

Information on these deep-sea fishes pertaining to LWRs generated from the study may be useful to fishery biologists in planning future research on the sustainable use of these fish species as part of fishery management.

Conclusion

The LWRs and condition factors depicted in this study are the paramount estimates for all the species from the Indian EEZ; however, due to the small sample size for some species (*A. blanfordii*) and the size range covered, some of them must be regarded as tentative. Also, inter-annual variations could not be ascertained in the study, warranting further analysis with more samples. The present study results contribute remarkably to the benchmark information for further modelling and population dynamics of deep-sea fishes along the Indian EEZ and help to corroborate the predictability of LWR estimates of data-poor species using Bayesian Models used in FishBase.

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Conflict of Interest

The authors of this paper declare no competing or conflicts of interest.

Author Contributions

KB, DN, KVA, RR: Sample collection, taxonomic identification, methodology, data analysis, writing-original draft, writing- review and editing, visualization. HM: Sample collection, taxonomic, identification, conceptualization, writing- review and editing.

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