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Depth wise variations in the maintenance of dimensional equality of the deep-sea fishes off southwest coast of India

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Abstract

An attempt is made to establish the depth specific variations in the length-weight relationships of ten species of deep-sea fishes inhabiting different depth zones along the southwest coast of India. The regression coefficients worked out for 10 species were compared using ANACOVA. The results revealed that both slope and elevation were significantly different in five species viz. *Psenopsis cyanea, Neoepinnula orientalis, Hoplostethus mediterraneus, Priacanthus hamrur* and *Cubiceps caeruleus* and pair wise comparisons of slopes showed significant difference both depth wise and sex wise in these fishes. On the contrary, no statistically significant difference was noticed in five other species.

Keywords: Length-weight relationship, deep-sea fishes, depth specific variation

Introduction

Establishing length-weight relationships in fishes is of great importance in fisheries research as they always serve as tools for assessing the changes taking place in fish populations. As opined by Diaz *et al.* (2000), no attempt has so far been made to assess variations, if any, in the length-weight relationship in deep-sea fishes inhabiting different depth zones which would serve as indices of various metabolic processes taking place in fishes inhabiting various depths. Information on length- weight relationships of deep-sea fishes from India is scanty (Khan *et al.*, 1996; Venu and Kurup, 2002a and Thomas *et al.*, 2003). In the present study, length-weight relationships of deep-sea fishes inhabiting different depth zones along the southwest coast of India have been worked out with a view to assess the variations, if any, in the maintenance of their dimensional equality with depths.

Materials and methods

Length and weight of 10 fish species were collected from 70°N and 20°N latitude during the fishing survey by FORV *Sagar Sampada* (Dept. of Ocean Development) in her Cruise no. 174, 183, 189, 196 and 197 conducted along the southwest coast of India from June 1999 to August 2001. Besides, specimens were also collected from the commercial boats with their operative base at Cochin, Munambam and Sakthikulangara, which had operated beyond 200m during November 2000 to February 2002. Information regarding depth of operation, name of fishing ground and the geographical position, etc., were made available through a pre- tested questionnaire supplied to the crew. In the survey cruises of FORV *Sagar Sampada*, fishing was conducted at 95 stations in the upper continental slope region of lat. 7^0 – 12^0 N with 38m High Speed Demersal Trawl II and 45.6m High Speed Demersal Trawl. The depth zones so covered were apportioned into five zones viz. 201-300m (Zone 1), 301-400m (Zone 2), 401-500m (Zone 3), 501-600 (Zone 4) and 601 – 700m (Zone 5). The length-weight relationships of 10 species of deep-sea fishes collected from these depth zones were worked out separately for males and females and the regression coefficients thus arrived at were statistically compared using ANACOVA. The number of specimens observed from various depths could not be uniformly maintained due to the differential availability of the specimens. Total length was measured from the tip of the snout to the tip of the upper caudal lobe to the nearest mm and weight was measured to the nearest 0.1g of both sexes (Kurup and Samuel, 1987). Length-weight relationship is expressed by the formula $W = aL^b$ (Le Cren, 1951). Statistical analyses of the data were done following Snedecor and Cochran (1967).

Results

The details of length-weight relationships established in males and females of five deep-sea fishes which showed significant difference between depths in ANACOVA and the same worked out from pooled data of five species which did not show similar difference are given in Table 1. The results of Baily's test for checking the deviation of these regression coefficients from isometric value of 3, if any, are also given in Table 1. It may be seen that the b values of males of *Psenopsis cyanea, Neoepinnula orientalis, Hoplostethus mediterraneus, Priacanthus hamrur* and *Cubiceps caeruleus* inhabiting 200-300m depth range departed significantly from the hypothetical value of 3. However, the same arrived at in the females of *P.cyanea* and *P. hamrur* inhabiting the same depth did not deviate significantly from isometry. Interestingly, females of all the above species inhabiting at 301-400 m did not follow isometrical growth pattern as shown by their male counterparts. However, the males of *N. orientalis* showed isometery at 301-400m depth, on the contrary, the males of *P. cyanea* and *H. mediterraneus* departed significantly from isometrical value of 3. Among the four species collected from depth range 400m and beyond such as *P. cyanea, N. orientalis, H. mediterraneus* and *P. hamrur,* the b values of females did not significantly depart from 3 while the males of *N. orientalis and H. mediterraneus* showed allometric growth pattern.

Results of the present study showed that both the slope and elevation were significantly different in five species viz., *P. cyanea, N. orientalis, H. mediterraneus, P. hamrur* and *C. caeruleus* (Table1). On the contrary, sex wise difference was seen only in *Psenes whiteleggii* while there was no statistically significant variation in males collected from various depth zones such as 201-300m and 301-400 m. No statistically significant difference was noticed both sex wise and depth wise in *Polymixia nobilis, Bathyclupea elongata, Porogadus trichiurus* and *Bembrops caudimaculatus.* The length ranges of the specimens used for the analyses in different depth zones are shown in Table 2. It could be seen from the table that there were not much difference in the length ranges in the specimens of the same species used for the length–weight relationship analyses from different depth zones. Therefore, these species were analyzed species-wise without prejudice to sex and depths.

The results of pair wise comparison of slopes of males and females of five species showed significant difference both depth-wise and sex-wise (Table 3). In *P. cyanea*, the b values arrived at were statistically different for both the sexes collected from 201-300m and 301-400m and from 301-400 and 501-600 (Table 3). The regression coefficients computed for *N. orientalis* collected from 201-300m and 301-400m for both sexes were statistically different, however, difference was not significant at 301-400 and 401-500m. Similar difference in coefficients between different depths was also discernible in both sexes of *H.mediterraneus* (between 301-400 and 401-500m) and *P. hamrur* (between 201-400m) while in *C. caeruleus* only females showed difference in 201-300m (Table 3).

Discussion

The regression coefficients worked out from length and weight measurements of deep-sea fishes varied from 1.90 in males of *P. cyanea* inhabiting 301- 400m to 4.09 in females of *N. orientalis* collected from 201-300m. Khan *et al.* (1996) have reported a highly differential growth pattern among males and females of *C. natalensis*, the former characterized by a low b value of 1.55. Highly skewed slope value of 1.974 has also been already reported in *Alepocephalus indicus* collected from 250-300m depth along the west coast of Indian EEZ (Thomas *et al.,* 2003).

Generally, the value of slope is expected to be 3 representing an isometric growth when the body proportion of fish remains constant at different lengths. But, often the fish may grow more slender as length increases (b= <3; negatively allometric) or may grow more stouter (b= >3; positively allometric) (Pauly, 1984). The results of Baily's test showed that regression coefficients worked out in some treatments in the present study did not depart significantly from isometry, though their values differed quantitatively from 3. Thus, b values arrived at in males and females of *P. hamrur* collected from 401-500m (3.67 and 3.31 respectively) and 2.49 in male *C. caeruleus* from 301-400m and 2.76 in female *H. mediterraneus* observed from 401-500m depth showed no significant variation from isometric value of 3.

In *P. cyanea* collected from the west coast of Indian EEZ, positively skewed b values were reported for both males and females (Khan *et al.*, 1996; Venu and Kurup, 2002b). In contrast, only the males collected from 201-300m depth showed a positive allometric growth in the present study. On the contrary, b values estimated for males and females of *P. hamrur* pooled depth-wise concurred with the findings of Khan *et al.* (1996) and Thomas *et al.* (2003). The species showed strong bathymetric preference and is distributed abundantly in shelf region up to 200m (Bande *et al.*, 1990; Sivakami *et al.*, 1998). This species is known to migrate across and parallel to the shelf, depending upon cold water currents. The negative

Table 1. *Depth-wise and sex-wise length-weight relationships in deep-sea fishes*

Species	Sex	Depth zone	n	a	b	sb	r		Baily's Test t
P. cyanea	M	201 -300	191	-5.6904	3.31	0.1103	0.9093	**	2.85
		301- 400	120	-2.5635	1.90	0.2075	0.6446	**	5.00
		501- 600	30	-4.8974	2.93	0.1786	0.9517		0.00
		Pooled	341	-5.2484	3.11	0.0933	0.8756		1.20
	F	201 -300	160	-5.1958	3.09	0.1122	0.9099		0.83
		301- 400	100	-2.7001	1.97	0.0902	0.9108	**	11.00
		501- 600	19	-5.4621	3.18	0.1611	0.9788		1.10
		Pooled	279	-4.2084	2.65	0.0804	0.8928	**	4.00
N. orientalis	M	201 -300	30	-7.4236	4.01	0.3292	0.9173	**	3.08
		301- 400	26	-5.4312	3.12	0.1758	0.9638		0.66
		401- 500	10	-6.6314	3.67	0.2131	0.9868	**	3.13
		Pooled	66	-6.4624	3.58	0.1369	0.9563	**	4.25
		201 -300	33	-7.6689	4.09	0.1631	0.9762	**	6.68
		301- 400	37	-5.1742	3.01	0.0962	0.9826		0.15
		401- 500	12	-5.8794	3.31	0.5561	0.8829		0.55
		Pooled	82	-6.3035	3.50	0.0825	0.9785	**	6.05
H.mediterraneus	M	301- 400	162	-4.0248	2.60	0.0830	0.9275	**	5.00
		401- 500	114	-2.7143	1.98	0.1064	0.8698	**	10.00
		Pooled	276	-3.4507	2.33	0.0688	0.8988	**	10.00
	F	301- 400	108	-1.9596	1.66	0.1454	0.7432	**	9.00
		401- 500	72	-4.3657	2.76	0.2467	0.8009		1.00
		Pooled	180	-3.1140	2.18	0.1173	0.8130	**	7.00
P.hamrur	M	201- 300	140	-4.3467	2.73	0.0610	0.9672	**	4.00
		401- 500	84	-5.7522	3.33	0.1996	0.8788		1.65
		Pooled	224	-4.1722	2.65	0.0531	0.9583	**	7.00
	F	201- 300	72	-4.7495	2.91	0.1007	0.9605		1.00
		401- 500	26	-6.2379	3.55	0.4922	0.8272		1.12
		Pooled	98	-4.5810	2.84	0.0700	0.9720	*	2.00
C.caeruleus	M	201 -300	58	-4.0638	2.54	0.0837	0.9708	**	6.00
		301- 400	32	-3.9129	2.49	0.3232	0.8147	*	2.00
		Pooled	90	-4.5740	2.78	0.0612	0.9793	**	4.00
	F	201 -300	94	-4.1686	2.58	0.1284	0.9025	**	3.00
		301- 400	43	-2.7483	1.99	0.2380	0.7943	**	4.00
		Pooled	137	-5.3997	3.17	0.0922	0.9474		1.85
P.whiteleggi	M	Pooled	123	-5.4943	3.26	0.0489	0.9866	**	5.32
	F	Pooled	309	-5.8092	3.40	0.489	0.9697	**	8.19
B. elongata		Pooled	67	-3.1340	2.15	0.0388	0.9896	**	21.98
P. nobilis		Pooled	83	-4.9890	3.04	0.1166	0.9453		0.34
P.trichiurus		Pooled	180	-4.8380	2.73	0.2837	0.5849		0.95
B.caudimaculatus		Pooled	132	-4.8760	2.85	0.1761	0.8178		0.84

Results of comparison of regressions of length and weight using ANACOVA

P. cyanea	Comparison of slopes F = 0.052496 (7,1224) = 15.29**	Comparison of elevation F= 0.040302 (7, 1231) = 10.86 **
N. orientalis	Comparison of slopes F = 0.0150365(7,200) = 3.18 **	Comparison of elevation F=0.0570988 (7, 207) = 11.23 **
H. mediterraneus	Comparison of slopes F = 0.0349 (5, 900) = 8.92 **	Comparison of elevation F=0.0290(5,905)= 7.11 **
P. hamrur	Comparison of slopes F = 0.0041 (5,7632) = 3.21**	Comparison of elevation F= 1.3209(5,637)= 1025.19.**
C. caeruleus	Comparison of slopes F = 0.0265 (5,442) = 9.69**	Comparison of elevation F = 0.0374(5,447)= 12.46 **

** = *Significant at 1% level* *= *Significant at 5% level*

allometry showed by these species can be attributed to the above behavioral pattern.

The results of the present study revealed that there exists significant variation in the maintenance of body dimension of the deep-sea fishes inhabiting at different depth zones. In respect of individual species, the length ranges of specimens collected from different depths were almost uniform. It is therefore, inferred that variations in the dimensions observed in individuals inhabiting different depth zones might be due to the habitat of various depth zones which show extreme variations. In mesopelagic fishes like *P. cyanea, N. orientalis* and *C. caeruleus,*

Table 2. *Length range of specimens used from various depth zones for computing the length-weight relationship*

Species	Sex	Length range (cm)		
		201-300 (m)	301-400 (m)	401-500 (m)
P.cyanea	F	14.1 - 23.5	13.6 - 22.9	
	M	14.3 - 23.2	14.4 - 22.1	
P. hamrur	F	19.7 - 21.1	20.2 - 21.2	
	M	17.2 - 22.2	18.1 - 21.7	
H. mediterraneus	F		12.1 - 16.8	11.2 - 17.4
	M		11.8 - 17.1	11.1 - 17.8
N. orientalis	F	15.4 - 24.2	14.1 - 24.3	13.9 - 22.2
	M	14.7 - 22.8	13.8 - 23.6	14.5 - 23.2
C. caeruleus	F	12.1 - 19.3	12.5 - 18.8	
	M	13.2 - 15.2	14.7 - 15.7	
P.whiteleggii	F	10.4 - 16.8		
	M	9.3 - 13.6		
B.elongata	Pooled	9.7 - 19.5		
P.nobilis	Pooled	11.5 - 18.9		
P.trichiurus	Pooled	28.5 - 64		
B. caudimaculatus	Pooled	16.7 - 18.9		

the relative growth in weight in relation to length has been found significantly different between the individuals collected from 200-300 and 300-400m depth zones. Furthermore, the regression coefficients worked out in males and females of these fishes collected from 200m revealed definite allometric growth pattern except in females of *P. cyanea*. These fishes are reported to be distributed in neritic waters in the range of 151-398m and are relatively abundant in deeper waters beyond 300m depth along southwest coast of India (Prasad and Nair, 1973; Philip *et al.*, 1984; Sivakami *et al.*, 1998). Skewness of b values from isometry has already been reported in some mesopelagic crustacean species (Ivanov and Krylov, 1980; Company and Sarda, 2000; Radhika, 2004). Strong allometrical growth pattern in three mesopelagic prawns *Sergestes arcticus, Passiphaea sivado* and *P. multidaitata* from Mediterranean Sea was reported by Company and Sarda (2000) which was attributed to their active swimming habits and diel vertical migrations in search for food.

On the contrary, except for males of *N. orientalis* and *H. mediterraneus*, all fishes collected from depths beyond 400m showed distinct isometric growth pattern. Moderate locomotary requirements and absence of dial migratory behavior in nektobenthic species help them to channelize their energy to somatic growth and maintenance of dimensional equality. According to Company and Sarda (2000), weight is not a limiting morphological factor of these categories of individuals, as they do not exhibit marked migratory habits. The b values of nektobenthic species of crustaceans have been reported to be around 3 owing to their moderate locomotary ability and absence of diel migratory behaviors (Company and Sarda, 2000). Similar results are also reported in nectobenthic deep-seas shrimp species *Plesionika* spp., *Parapandalus* spp. and *Heterocarpus* spp. from Indian waters (Radhika, 2004).

In contrast, the available reports also suggest that deep-sea fishes generally exhibit a negative allometric growth pattern when compared to their counter parts inhabiting shallow depths or other coastal species, as part of their deep-sea adaptation (Thomas *et al* ., 2003). The authors have reported that, of the twenty-two deep-sea fishes studied, fourteen showed slightly negative allometric growth. According to the above authors, in 8 species, b values were close to 3. The results of the present study showed that length-weight relationships worked out in male *H. mediterraneus* and female *C. caeruleus* followed negative allometry in higher depth ranges. Surprisingly, it is worth reporting that fishes collected from deeper waters beyond 400m depth except males of *N. orientalis* and *H. mediterraneus* followed isometric growth

Table 3. *Results of pair wise t-test conducted on regression coefficients of deep-sea fishes*

Between treatments		*PC*			*NO*			*HM*			*PH*			*CC*	
		df	t		df	t		df	t		df	t		df	t
201-300 M	301-400 M	307	6.14	**	52	2.06	*							86	0.18
201-300 M	401-500 M				36	0.38					220	2.56	*		
201-300 M	501-600 M	217	0.89												
201-300 M	201-300 F	347	1.34		63	3.18	**				208	1.13		148	0.28
201-300 M	301-400 F	287	8.13	**	59	0.22								97	2.43
201-300 M	401-500 F				38	0.95					162	1.5			
201-300 M	501-600 F	206	0.25												
301-400 M	401-500 M				32	1.46		272	4.69	**					
301-400 M	501-600 M	146	2.54	*											
301-400 M	201-300 F	276	0.32		59	0.53								122	0.3
301-400 M	301-400 F	216	5.87	**	55	3.63	**	266	6.02	**				71	1.16
301-400 M	401-500 F				34	0.42		230	0.68						
301-400 M	501-600 F	135	2.09	*											
401-500 M	201-300 F				43	2.11	*				152	1.95			
401-500 M	301-400 F				39	0.8		218	1.81						
401-500 M	401-500 F				18	0.5		182	2.98	**	106	0.43			
501-600 M	201-300 F	186	0.47												
501-600 M	301-400 F	126	3.65	**											
501-600 M	501-600 F	45	0.95												
201-300 F	301-400 F	256	7.53	**	66	5.69	**							133	2.45
201-300 F	401-500 F				45	0.81					94	1.61			
201-300 F	501-600 F	175	0.2												
301-400 F	401-500 F				99	1.61		176	3.69	**					
301-400 F	501-600 F	115	3.75	**											

PC = *P. cyanea*, NO = *N. orientalis*, HM = *H. mediterraneus*, PH = *P. hamrur*, CC = *C. caeruleus*, *M = Male, F= Female. ** Significant at 1% level, * Significant at 5% level*

in terms of length and weight and maintained dimensional equality well when compared to their counterparts inhabiting in relatively shallow waters. Since this being a pioneer study in this regard, the present results cannot be compared with previous findings.

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