Length-weight relationship of some deep-sea fish inhabiting the continental slope beyond 250m depth along the West Coast of India

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Abstract

The length–weight relationships of 22 species of deep-sea fishes inhabiting the continental slopes beyond 250 m depth along the West Coast of India are presented. The parameters **a** and **b** of the equation $W=a L^b$ were estimated. The fish samples were collected from trawl surveys during 1999 to 2001 on board the *FORV Sagar Sampada* at a depth range of 250 to 600 m in the area between 7°N and 20°N latitude. The value of **b** ranged from 1.94 to 3.36.

Introduction

With the declaration of India's Exclusive Economic Zone (EEZ) with an exploitable area of 2.02 million km^2 in 1976, there have been attempts by scientists to delineate the deep-sea resources beyond the depth of 250 m and their potential exploitation, from the continental shelf edge of India. With this objective in view, many resource surveys were conducted in the neritic and oceanic waters along the continental slope of the Indian Coast. The potential yield from the EEZ of India was estimated to be 3.9 to 4.5 million tonnes in 1995 as against the actual exploited production of 2.3 million tonnes in the same year (Shivakami 1998). Thus, non-conventional fishery resources distributed in the continental slope of the Indian EEZ offer a promising potential in the Indian fishery scenario, which can be further improved by a thorough knowledge of the exploitable biomass of the EEZ. In order to make an estimate on the biomass, it is also necessary to know the length–weight relationships of the species collected from the same locality.

Length-weight relationships of fishes are important in fisheries biology because they allow the estimation of the average weight of the fish of a given length group by establishing a mathematical relation between the two (Beyer 1987). They are also useful for assessing the relative well being of the fish population (Bolger and Connolly 1989). Like any other morphometric characters, the length-weight relationship can be used as a character for the differentiation of taxonomic units and this relationship is seen to change with various developmental events in life such as metamorphosis, growth and the onset of maturity. Besides this, the length-weight relationship can also be used in setting yield equations for estimating the number of fish landed and comparing the population in space and time (Beverton and Holt 1957). The empirical relationship between the length and weight of the fish thus enhances the knowledge of the natural history of the deep-sea fish about which studies are scant for the Indian Ocean.

About 120 fish species have been identified during the various trawl survey activities on board *FORV Sagar Sampada* along the west coast of India. The length-weight relationship of 22 species are presented here. This paper aims to contribute to the length-weight relationship data for direct use in fishery assessment and also for allowing future comparisons between populations of the same species encountered at different locations. The length-weight ratios computed for the various species in this paper are useful for the various ecological parameters of the deep-sea, which govern the dimensional variation exhibited by the fish as a part of adaptation for their deep-sea habitat. The fact that not much quantitative information is available on the biology of the deep-sea fish (including length-weight relationships) in the Indian Ocean justifies our objective.

Materials and methods

The fish samples were collected from the experimental trawling operations conducted on board the *FORV Sagar Sampada* along the west coast of India during her cruises from 1999 to 2001. The trawl survey activities were conducted as part of the Department of Ocean Development sponsored project on "*The Stock Assessment and Resource Mapping of Deep Sea Fish Along the EEZ of India*". The sampling area lies between 7°N and 20°N latitude at a depth range from 250 m to 750 m (see Figure 1). The gears used were the Otter Trawl Expo model (fish version) and HSDT II (crustacean version). Random samples were collected from each haul for biological investigation on length frequency, sex, maturity, food, etc. The fish were identified up to the species level using Heemstra and Randall (1993). The total length (TL) of the fish was measured from the most anterior part of the head with the mouth closed to the farthest tip of the caudal fin. The total weight (W) of the fish was recorded to the nearest 10 g using a top-loading

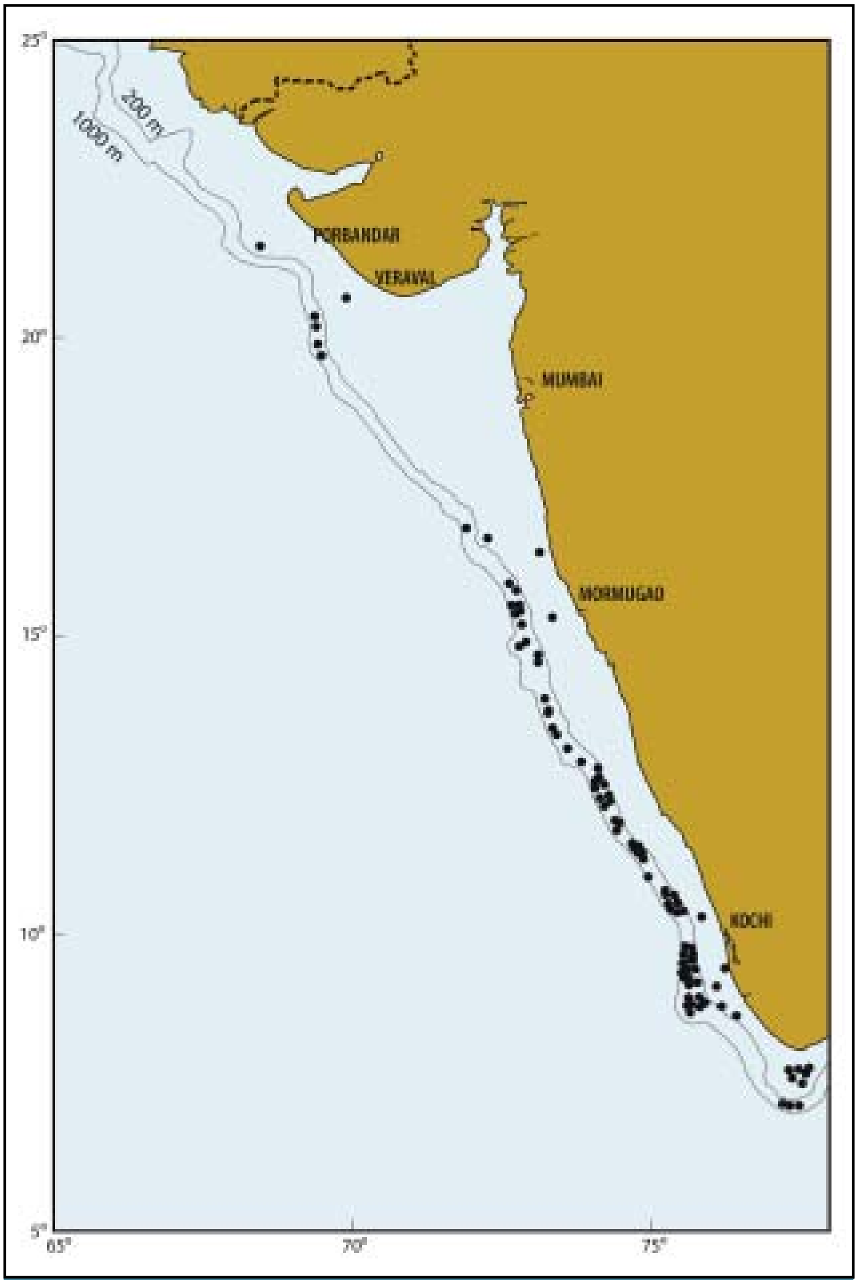

Fig. 1. The western continental shelf of India with dots indicating the stations of bottom trawl operations of FORV Sagar Sampada during the cruises from 1999-2001

balance. Sample size (n) varied depending on the availability of the deep-sea fish in the area surveyed. The length-weight relationship was calculated using the formula: $W = a\,L^b$ (Pauly 1984) and was logarithmically transformed into: **log W = log a + b log L** where **W** is the weight of the fish in grams and **L** is the length of the fish measured in centimeters. The parameter **a** (proportionality constant) and **b** (regression coefficient) of the length-weight relationship were estimated by the method of least square regression (Zar 1984) for the combined sex of each species.

Results and discussion

Results of the length-weight relationship analysis of 22 fish populations representing 15 families, 18 genera and 22 species are summarized in Table 1. Sample sizes of species studied ranged from 25 to 284 individuals. The smallest sample size corresponds to the infrequent species that occurs under such depths mentioned and the largest samples belong to those which are frequently encountered below these depths in huge numbers. The determination coefficient (r^2) of the non-linear regression is plotted against the sample sizes. The regression values (or r^2) were always over 0.95 for n>50.

With the exception of the **b** value for *Alepocephalus indicus* (1.974), which indicates an acute negative isometric growth, the distribution of values for the other deep-sea fin species seem to be close to 3. The value of **b** varied between 1.974 (*Alepocephalus indicus*) and 3.36 (*Poragadus trichurus*).

For an ideal fish which maintains dimensional equality, the isometric value of **b** would be 3. This has occasionally been observed (Allen 1938). The slope (**b**) value less than 3 indicates that a fish becomes more slender as it increases in length. A slope value greater than 3 denotes stoutness or allometric growth (Pauly 1984). However, deviation from isometric growth is often observed, as most fish change their body shape as they grow.

Correlations in the regression coefficient were found to be in line when compared to similar deep-sea species counterparts located in the Atlantic waters. The fish belonging to the family Polymixiidae presented in Table 1 exhibited the **b** value of 3.05, which was similar to the values estimated by Diaz et al. (2000) for the same family in Colombian waters. A regression coefficient (**b**) tending closely towards 3 was computed for *Chlorophthalmus agassizi*, which was found to be in line with the length-weight characteristics of an assemblage of *C. agassizi* captured along the Brazilian coast by Haimovici and Velasco (2000).

The two species belonging to the family Zeidae also showed similar values, of which *Zenopsis conchifer* collected from the Indian waters showed a slight negative allometric growth with a **b** value of 2.5. This is consistent with the findings of Haimovici and Velasco (2000) who reported a **b** value of 2.9. However, *Cyttopsis rosea* captured from the Indian

Table 1. Length-weight relationship and related statistics of 22 deep-sea finfish species collected along the West Coast of Indian EEZ beyond 250 m depth

Taxa/Species	n	Length (cm)		Weight (g)		Regression Parameters			Depth (m)	
		min	max	min	max	a	b	r^2	min	max
Stromateidae										
Psenopsis cyanea	229	14.3	23.5	65.3	336.7	-2.376	3.302	0.965	250	300
Nomeidae										
Psenes whiteleggii	182	11.0	18.2	18.9	64.6	-4.437	2.936	0.985	250	400
Cubiceps pauciradiatus	68	11.2	19.3	18.4	80.0	-6.548	3.078	0.975	300	400
Cubiceps caeruleus	75	14.5	28.5	25.0	85.0	-2.282	2.161	0.986	300	400
Chlorophthalmidae										
Chlorophthalmus punctatus	222	14.4	22.8	25.0	85.2	-3.571	2.576	0.945	250	300
Chlorophthalmus bicornis	100	9.9	17.5	7.4	48.5	-2.795	2.900	0.989	250	300
Chlorophthalmus maculatus (*Paraulopus maalatus**)	56	13.4	17.3	20.4	34.9	-4.351	2.790	0.968	250	300
Chlorophthalmus agassizi	125	13.5	24.5	22.8	213.0	-6.347	2.987	0.945	300	400
Polymixiidae										
Polymixia nobilis	50	11.5	16.9	15.0	62.0	-2.080	3.059	0.951	250	300
Moridae										
Physiculus natalensis	30	16.0	24.9	25.0	76.0	-1.637	2.538	0.968	250	300
Ophidiidae										
Poragadus trichiurus	128	44.0	64.0	150.0	910.0	-6.340	3.361	0.952	400	600
Zeidae										
Zenopsis conchifer	85	15.0	31.0	65.0	585.0	-3.281	2.586	0.985	300	400
Cyttopsis rosea	20	8.9	18.5	70.4	69.0	-6.589	3.089	0.956	300	400
Neoscopelidae										
Neoscopelus microchir	25	9.0	18.5	43.0	60.0	-4.526	2.940	0.985	300	400
Trachichthyidae										
Hoplosthethus mediteraneus	96	10.5	25.0	43.0	60.0	1.050	3.075	0.994	300	400
Percophidae										
Bembrops caudimacula	25	16.0	19.0	30.0	45.0	-2.698	2.808	0.982	250	300
Gemphylidae										
Neoepinnula orientalis	67	14.0	26.5	20.0	144.0	-2.630	2.986	0.965	250	300
Rexea prometheodes	96	15.6	29.0	25.0	95.0	-6.011	3.118	0.991	250	300
Synodontidae										
Saurida undosquamis	39	19.0	32.5	45.0	210.0	-5.177	3.053	0.938	250	300
Sphyraenidae										
Sphyraena obtusata	40	20.0	26.0	44.5	109.6	-4.766	2.888	0.952	250	300
Alepocephalidae										
Alepocephalus indicus (*Alepocephalus longiceps**)	17	13.0	19.5	19.0	25.3	0.290	1.974	0.943	250	300
Priacanthidae										
Priacanthus hamrur	284	14.0	27.7	35.7	257.0	-1.757	2.856	0.989	250	300

** Valid name on FishBase (www.fishbase.org)*

Ocean at depths ranging from 300 m to 400 m and those reported from the upper continental slope off Colombia by Diaz et al (2000) showed a **b** value which was in accordance with the ideal value of 3. Thus, the population in both waters showed isometric growth. Another species, which indicated similar results in accordance to its counterparts in the Atlantic waters, is *Neoscopelus microchir* exhibiting a slightly negative allometric growth.

It is, however, very interesting to note that many of the deep-sea species presented in this study exhibit a trend of negative allometric growth (Table 1) when compared to the coastal species or its counterparts inhabiting lesser depths i.e., almost 14 species exhibit a slightly negative allometric growth. This may be attributed to the ecological parameters at the depth at which these species have carved their ideal niche. The deep-sea environment is mainly characterized by permanent darkness, extremely low temperature (around 2°C), salinity from 34 ppt to 35 ppt, very low productivity, intense pressure, extremely low dissolved oxygen content and nutrients. Much of the deep-sea is permanently oligotrophic (Abhijit Mitra 1998). Biological oceanographers generally accept a number of conclusions about the ecology and the ecological processes in the deep-sea. They realize that the biomass tends to decrease with depth, and that growth is usually very slow. The life spans are longer, the biological communities are diverse and widespread and they are zoned by depth. As plants rarely grow in the deep-sea, there is only an indirect link to primary production through food webs and ladders of migration and ultimately, most deep-sea production has to depend on the productive zone at the surface (Gage and Tyler 1991). Mauchline and Gordon (1991) pointed out the scarcity of resources in the deep-sea and how a trophic connection through pelagic animals is important for deep-sea demersal fish to obtain the nutritional benefits of the productive zone.

Thus, to counter the scarcity of resources many adaptations are seen with regards to growth and maintenance of the dimensional equality of the body in an allocated space. Larger fish grow very slowly, and restricted energy means that the attainment of near-ultimate size must precede reproduction (Large et al. 1999). After that juncture in the growth phase, most of the energy derived is diverted to the reproductive processes rather than general somatic growth. Somatic growth in the deep-sea is not given much importance due to the lack of nutritional resources at low depths when compared to coastal species that attain considerable growth before commencement of reproduction. Thus, a drastic change in the maintenance of dimensional equality of the body parameter can be expected in accordance with a change in depth and must probably be linked with the adaptation of the deep-sea fish.

The length-weight relationship observed by Letourneur et al. (1998) in the case of *Sphyraena obtusata* and *Saurida undosquamis* collected at depths beyond 250 m was reported to be 2.8 and 2.93, respectively, which was in line with the results of the present study on the population of *S. obtusata* and *S. undosquamis* collected from the west coast of India. However, Muthiah (1994) came across a regression coefficient of 3.308 on a population of *S. undosquamis* captured from lesser depths along the west coast of the Indian EEZ. This points to a departure of the regression coefficient **b** from the ideal value of 3 towards a negative allometric growth trend as the depth increases.

In Indian coastal waters, comparative observations on the results obtained by Philip and Mathew (1996) on a population of *Priacanthus hamrur* obtained from the coastal waters and the present study point out similar observations of a negative allometric growth trend with an increase in depth. In a population of *P. hamrur* collected along the coastal waters from the east coast of India, the above authors reported the regression coefficient **b** to be 3.11. This indicated a positive allometric growth, i.e., the fish grew stouter with increased length, which was different when compared to the length-weight ratio of *P. hamrur* captured from depths beyond 250 m. This may be attributed to the difference in depths at which the fish were caught where there is a distinct pattern in the distribution of the population with respect to age and sex (Philip 1994) across the depth zones.

Several factors affect the accuracy of the length-weight relationship depending on the condition of the fish caught during different seasons, the depth of capture, geographical locations, sex, length ranges, sample size, etc. It can be concluded that the deep-sea finfish populations represented in this paper share more or less similar population characteristics when compared with those of related species encountered at different geographical locations at similar depths. They also exhibit a general trend of negative allometric growth when compared to coastal populations, which may be attributed as one of the deep-sea adaptations.

However, in the case of the deep-sea, dominance by a single species tends to be lower, and species diversity is high. Species are widespread horizontally, but because the fauna is zoned according to depth, quite different fish communities are encountered at different depths of just a few hundred meters at a single locale. Considering the slow growth, longevity and uncertain recruitment over long periods of time, combined with high biodiversity in the individual samples, it is not easy to get information on any one species very quickly. It is necessary to initiate further efforts notwithstanding the above constraints to develop a comprehensive knowledge about the biology of the deep-sea fish and their mode of life in an extremely limited ecological condition.

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