Available online at: www.mbai.org.in doi:10.6024/jmbai.2022.64.2.2336-19

Length-weight relation and relative condition factor of six deep-sea fishes from the south-eastern Arabian Sea

A. X. Treasa Augustina[1, 2], Miriam Paul Sreeram[2*], K. M. Sreekumar[2] and K. R. Aju[1, 2]
[1]Cochin University of Science and Technology, KSCSTE, Kochi- 682 022, Kerala, India.
[2]ICAR-Central Marine Fisheries Research Institute, Kochi- 682 018, Kerala, India.

*Correspondence e-mail: miriampaul@yahoo.com

Received: 08 Jan 2022 Revised: 13 June 2022
Accepted: 05 July 2022 Published: 25 Sep 2022

Short communication

Abstract

The present study estimates the length-weight relationships of six deep-sea finfishes belonging to six families and four different orders. Of the six species studied, first-time information is provided for three species: *Polyipnus indicus, Antigonia indica* and *Champsodon vorax*. The samples were collected from the south-eastern Arabian Sea by deep-sea trawlers landing at Sakthikulangara Fisheries Harbour, Kollam, Kerala, India. The *b* value ranged from 2.14 to 3.46, and r^2 values ranged from 0.903 to 0.968. Four species (*Bathyclupea hoskynii*, *Synagrops japonicus*, *C. vorax* and *P. indicus*) exhibited negative allometric growth, and two species (*Eridacnis radcliffei* and *A. indica)* exhibited positive allometric growth. The *b* values obtained from the present study were compared with the Bayesian model in Fish Base. Relative condition factor estimates showed lower ranges for *E. radcliffe* and *S. japonicus,* indicating that some individuals had a suboptimal status of K>1.

***Keywords**: Length-weight relation, b value, allometric growth, southwest coast, deep-sea fish*

Introduction

Organisms tend to increase in size concerning length and weight during their developmental stages, which is influenced by ecological and physical factors like food availability, gonadal development, spawning conditions, sex, age, temperature, oxygen and other water quality factors, time of fishing etc. (Erzini, 1994; Kuriakose, 2014). The length-weight relationship is majorly employed for analysing fishery population parameters in a given geographic region (Morato *et al*., 2001; Aura *et al*., 2011). It is a useful tool for the estimation of weight from length data since it is difficult to determine weight accurately in the field. The length-weight relationship also indicates taxonomic differences and life history stages of fish (Venkataramanujam and Ramanathan, 1994; Froese *et al*., 2011; Froese *et al*., 2014). This relationship can also be used to infer the prey size and understand food web dynamics (Kumar *et al*., 2017). Apart from the uses mentioned above, the b value in length-weight relationships determines whether the fish's somatic growth is in isometric or allometric condition (Le Cren, 1951; Ricker, 1975). The well-being and robustness of the fishes are represented by the relative condition factor, which reflects the state of sexual maturity and degree of nourishment. It varies with the age and sex of the fish (Froese *et al*., 2006). Estimation of length-weight analysis is considered a routine procedure which often does not warrant publication; however, a meta-analysis of a large number of length-weight relationships reveals information about the ecology of the species (Froese, 2006; De la Hoz *et al*., 2016).

Studies on the length-weight relationship of deep-sea fishes from the western Indian Ocean are scarce and scattered (Aura *et al*., 2011), with only limited information on the distribution, diversity, ecology and life history stages of these species (Kumar *et al*., 2016). Major works on the length-weight relationship of Indian deep-sea fishes are from the southern coastal regions (Thomas *et al*., 2003; Jayaprakash *et al*., 2006; Bineesh *et al*., 2012; Sreedhar *et al*., 2013; Bineesh *et al*., 2018; Sileesh *et al*., 2020b). A few are available from the eastern coastal region (Kumar *et al*., 2016, 2017; Sileesh *et al*., 2020a). Since fishing activities are recently being expanded to the deep-sea regions, it is important to gather basic information, such as the length-weight relationship, which has a vital role in ecological assessments and monitoring (Orlov and Binohlan, 2009). The objective of the present study was to analyse the length-weight relationship and relative condition factor of six deep-sea species, namely the Oceanic basses, the Indian deep-sea herring *B. hoskynii* Alcock, 1891 (Order: Acropomatiformes, Family: Bathyclupidae); the greedy gaper *C. vorax* Günther, 1867 (Order: Acropomatiformes, Family Champsodontodae) and the blackmouth splitfin *S. japonicus* (Döderlein, 1883) (Order: Acopomatiformes, Family: Synagropidae); the marine Hatchetfish *P. indicus* Schultz, 1961 (Order Stomiiformes, Family: Sternoptychidae); the deep body boarfish *A. indica* Parin and Borodulina, 1986 (Order: Acanthuriformes, Family: Antigoniidae) and the pigmy Ribbon tail catshark *E. radcliffei* Smith, 1913 (Order: Carchariniformes, Family: Proscylliidae).

Material and methods

Samples for the present study were collected during 2020 - 2021 from deep-sea trawler bycatch from Sakthikulangara Fisheries Harbour, Kollam, Kerala, India, every month from October to May, which is the duration of deep-sea fishery season here. Geographical coordinates and depth of fishing were collected from the boat captains of the trawlers from which samples were collected. The trawling grounds were located between a depth range of ~290-450m (8°05′00″N–9°00′00″N, 75°05′001″E-76°05′00″E), Fig. 1. The number of specimens examined for the selected species was as follows: *A. indica* n=34, *E. radcliffei* n=35, *B. hoskynii* n=50, *C. vorax* n=62, *S. japonicus* n=75 and *P. indicus* n=118. The total length and weight of all the species were recorded in the fresh condition to an accuracy of 0.1 cm and 0.1 g, respectively. The species were identified up to the species level using standard identification keys and research articles (FAO, 1984; Harold, 2002; Prokofiev *et al*., 2020). Estimation of the length-weight relationship

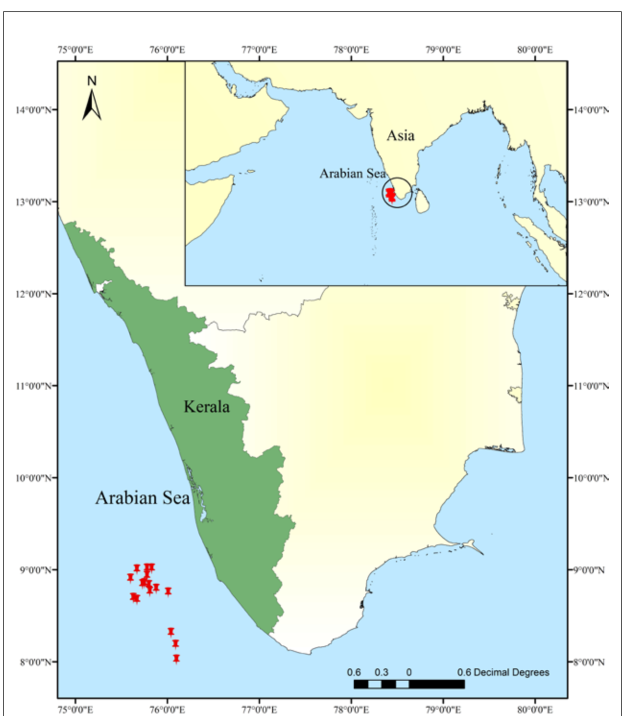

Fig. 1. Map indicating deep-sea trawling locations

was inferred from the least square regression method (Le Cren, 1951; Zar, 1999) and expressed by the equation $W = aL^b$. The length-weight equation was transformed to logarithmic form $\log_{10}W = \log_{10}a + b \log_{10} L$ following Froese *et al.* (2011), and curvilinear plots of length and weight values were also visually inspected for any possible outlier values in the data. The coefficient of determination (r^2) was estimated, which indicates the validity of the analysed data (Le Cren, 1951; Zar, 1999; Froese *et al*., 2014). All analyses were performed using the FishR Vignette package (Ogle, 2013) implemented in R software (R Core Team, 2020). Fish growth was considered to be isometric when b value=3, positive allometric when b>3and negative allometric when b<3, following Froese, 2006. A student t-test was applied to determine the significant difference between b values from isometric value (b=3) (Pauly, 1984; Economou *et al*., 1991; Spiegel, 1991). The fish's relative condition factor was calculated by following the method postulated by Le Cren (1951).

Results and discussion

The present study provides information on the length-weight analysis of three species *C. vorax* (Fig. 2), *P. indicus* (Fig. 3) and *A. indica* (Fig. 4), for which the same are hitherto not available. It also provides further information on the length-weight relationships of *B. hoskynii* (Fig. 5), *S. japonicus* (Fig. 6) and *E. radcliffei* (Fig. 7), which is useful for comparison with reports of the same from other locations in India and other oceans. All the six species investigated are distributed widely in the Indian Ocean except for *P. indices,* which is reported from the Western Indian Ocean as occurring on the east African coast (Froese and Pauly, 2021) and is also mentioned in recent works from Indian waters (Hashim, 2012). The length-weight analysis for the six selected species is presented in Table 1, representing the sample size, length and weight range and parameters like *a*, *b*, 95% confidence limits of *a* and *b,* coefficient of determination r^2 and t-test significance. Sample sizes ranged from 34 for *A. indica* and 118 for *P. indicus*. The *b* value ranged from 2.14 for *C. vorax* to 3.46 for *E. radcliffei*. The r^2 values ranged from 0.903 for *B. hoskynii* to 0.968 for *A. indica.* The *b* values obtained for *B. hoskynii*, *S. japonicus, C. vorax* and *P. indicus* were 2.6, 2.82, 2.14 and 2.19 respectively ($b<3$, t-test, $P<0.05$), indicating negative allometric growth *i.e.*, larger specimen have an elongated body shape and/or smaller specimen are in better body condition at the time of sampling. The *b* values observed for *A. indica* and *E. radcliffei* were 3.46 and 3.29 respectively ($b>3$, t-test, $P<0.05$), indicating positive allometric growth and inferring that the larger specimen had a broader body than the smaller specimen. Thomas *et al.* (2003), investigating deep-sea fish species, found the *b* value to range from 1.97 to 3.3, with many of the deep-sea species exhibiting a trend of negative allometric growth. The key factor influencing the difference in *b* value is seasonal variation in the growth patterns, depth, fishing gear used, geographical locations, and physic-chemical factors (Sreedhar *et al.*, 2013; Kumar *et al.*, 2016). From the selected six species studied, the *b* values of three species are new to science: *P. indicus*, *A. indica* and *C. vorax*. Comparison of the results of length-weight analysis of these three species with Baysian length-weight estimates based on models which use known length-weight relationships of species of the respective subfamilies showed that the first two species exhibited relatively low *b* value (2.14 and 2.19 respectively) in actuality *viz-a-viz* the predictions (3.12 and 2.97 respectively). In the case of *A. indica* the value obtained in this study is 3.29, which is much higher than the estimated 2.97 as per the above Bayesian model. In comparison with the previous studies of length-weight relationships of the species from similar regions, the *b* values reported for *E. radcliffei* (*b*=3.46) in this study fall in the same range as that of the previous reporting (*b*=3.28-3.55) (Akhilesh, 2014). *S. japonicus* shares similar values (*b*=2.82) comparable with that in the previous study (*b*=2.86) (Kumar *et al.*, 2018). In the present study, the b value of *B. hoskynii* was observed as 2.60. This value is considerably lower than the *b* value of 3.1089 reported by Sileesh *et al.* (2020b). The specimen of this species examined in the present study included 50 individuals in the length range of 9.5-19.5 cm, covering a wider size range, whereas the previous study was based on 34 individuals in the size range of 13.6-19.0 cm, which did not include smaller sized individuals.

The relative condition factor for the selected six species are in the following range: *E. radcliffei:* 0.7408-1.4557, *S. japonicus*: 0.8779-1.1765, *A. indica*: 0.9141-1.2376, *B. hoskynii*: 0.9775-1.1961, *P. indicus*: 0.9770-1.1676 and *C. vorax*: 0.9949-1.1491. A condition factor of value K<1 is considered poor, and body proportions are expected to be long and thin, whereas a K value =1.2 and up to 1.39 signifies a moderate condition and >1.4 indicate a well-proportioned fish (Barnham and Baxter, 1998).

Fig. 2. Indian deep-sea herring (*B. hoskynii*)

Fig. 3. Greedy gaper (*C. vorax*)

Fig. 4. Blackmouth splitfin (*S. japonicus*)

Fig. 6. Marine hatchetfish (*P. indicus*)

Fig. 5. Pygmy ribbon tail catshark (*E. radcliffei*)

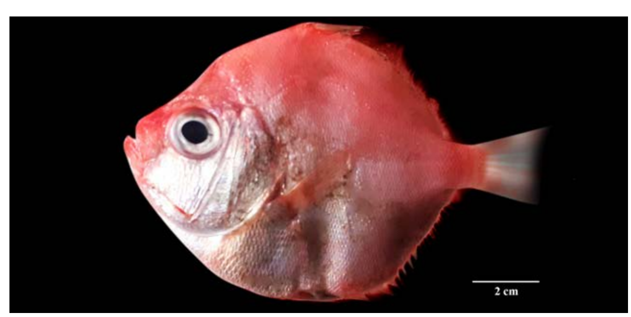

Fig. 7. Deep-body boarfish (*A. indica*)

Table 1. Length-weight relationships for 6 deep-sea fish, south-east Arabian Sea

Species	N	Total length (cm)			Total weight (g)		Parameters of relationships							Growth behaviour
		Min	Max	Max length reported in Indian waters	Min	Max	a	b	95% CL a	95% CL b	r^2	t-test significance		
Eridacnis radcliffei	35	13	22.7	25.7 (Akhilesh, 2014)	4.02	28.60	0.00056	3.46	0.00019 - 0.00164	3.07-3.85	0.905	0.023		Positive allometry
Antigonia indica	34	5	10.7	10.7 (present study)	2.55	31.96	0.0127	3.29	0.0083 - 0.0195	3.09-3.49	0.968	0.009		Positive allometry
Bathyclupea hoskynii	50	9.5	19.5	19 (Sileesh *et al.*, 2020b)	6.44	39.22	0.0215	2.60	0.0114 - 0.0405	2.35-2.85	0.903	0.000		Negative allometry
Synagrops japonicus	75	10.5	20	20 (Kumar *et al.*, 2018)	11.40	91.2	0.0151	2.82	0.0092 - 0.0245	2.63-3.01	0.923	0.029		Negative allometry
Champsodon vorax	62	6	10.8	10.8 (present study)	1.77	5.61	0.0368	2.14	0.0257 - 0.0527	1.98-2.31	0.9182	0.000		Negative allometry
Polyipnus indicus	118	4.4	7.5	7.5 (present study)	1.12	4.95	0.0589	2.19	0.0394 - 0.0879	1.96-2.43	0.932	0.000		Negative allometry

In accordance with this categorisation, the lower ranges of condition factor values for *E. radcliffei* and *S. japonicus* fall below 1.0, indicating that some individuals of these species were not in optimum condition. The relative condition factor can vary depending on seasonal and breeding changes where, at the onset of gonad development, muscle tissues are converted into gonads, and feeding intensity will be low; therefore, the condition factor of the fishes tends to be low (Froese, 2006; Mathialagan *et al.*, 2014). The peak breeding season of *E. radcliffei* was observed from December to February along the Kerala coast (Nair and Appukuttan, 1973; Akhilesh, 2014). A proportion of the specimen collected may have been in the early breeding stages. Most of the *E. radcliffei* specimens were collected in the November to February period. A second and more compelling factor noticed was that in this species, individuals below 15 cm in size were much thinner and ribbon-like with low body weight compared to those above it, which may have influenced overall values.

The present study provides information on data-poor deep-sea fishes. The length-weight estimation and relative condition factor results provide baseline knowledge of some basic fishery estimation parameters. Future population dynamics studies are imperative if there is to be an evaluation of current exploitation rates of low-economic value species and the adoption of conservation measures.

Acknowledgements

The authors are deeply grateful to the Director, CMFRI for the encouragement and all the provisions made for the study. The authors express their sincere thanks to the boat owners of Sakthikulangara fish landing centre for the help rendered during the sample collection. The first author is grateful to Kerala State Council for Science and Technology for the financial assistance provided through the Research Fellowship and Research Contingency and Cochin University of Science and Technology is also thankfully acknowledged.

References

Akhilesh, K. V. and N. G. K. Pillai. 2014. Fishery and biology of deep-sea chondrichthyans off the southwest coast of India (Doctoral dissertation, Cochin University of Science and Technology).

Aura, C. M., C. N. Munga, E. Kimani, J. O. Manyala and S. F. Musa. 2011. Length-weight relationships for nine deep sea fish species off the Kenyan coast. *Pan-Am. J. Aquat. Sci.*, 6: 188-192.

Barnham, C. and A. Baxter. 1998. Condition Factor, K, for Salmonid Fish. *Fisheries Notes*, p. 1- 3.

Bineesh, K. K., S. Manju, K. V. Akhilesh and N. G. K. Pillai. 2012. A preliminary study on the length-weight relationship of *Sacura boulengeri* (Heemstra, 1973) from Indian waters. *Turk. Zool. Derg.*, 36: 267-270.

Bineesh, K. K., M. Nashad, K. V. Aneesh Kumar, K. V. Akhilesh and M. Hashim. 2018. Length-weight relationships of eight deep-sea fish species collected from the southwest coast of India, *J. Appl. Ichthyol.*, 34 (5): 1220-1222.

De La Hoz, M. J., J. Motta and J. Paramo. 2016. Length-weight relationships for 36 deep-sea fish in the Colombian Caribbean Sea. *J. Appl. Ichthyol.*, 32(6): 1356-1359.

Economou, A. N., C. H. Daoulas and T. Psarras. 1991. Growth and morphological development of chub, *Leuciscus cephalus* (L.), during the first year of life. *J. Fish Biol.*, 39(3): 393-408.

Erzini, K. 1994. An empirical study of variability in length at age of marine fishes. *J. Appl. Ichthyol.*, 10: 17-41.

FAO. 1984. FAO species identification sheets for fishery purposes. In W. Ficher, & G. Bianchi (Eds.), Western Indian Ocean (Fishing area 51). Rome: Food and Agricultural Organization of the United Nations. p. 1-4

Froese, R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *J. Appl. Ichthyol.,* 22(4): 241-253.

Froese, R., A. C. Tsiklirans and K. I. Stergiou. 2011. Editorial note on weight-length relations of fishes. *J. Appl. Ichthyol.*, 41: 261-263.

Froese, R., J. T. Thorson and R. B. Jr. Reyes. 2014. A Bayesian approach for estimating length- weight relationship in fishes. *J. Appl. Ichthyol.*, 30: 78-85.

Froese, R. and D. Pauly. 2021. *Fish Base*. World Wide Web. Electronic publication. Available from: www.fishbase.org (accessed 6 December 2021).

Harold, A. S. 2002. Order Stomiiformes: Gonostomatidae. In: Carpenter, K. E. (Ed.). The Living Marine Resources of the Western Central Atlantic. Bony fishes Part 1 (Acipenseridae to Grammatidae). FAO, Rome, 2: 889-892.

Hashim, M. 2012. Distribution, diversity and biology of deep-sea fishes in the Indian EEZ. Doctoral dissertation, Cochin University of Science and Technology.

Jayaprakash, A. A., B. M. Kurup, U. Sreedhar, S. Venu, T. Divya, A. V. Pachu and S. Sudhakar. 2006. Distribution, diversity, length-weight relationship and recruitment pattern of deep-sea finfishes and shellfishes in the shelf-break area of southwest Indian EEZ. *J. Mar. Biol. Ass. India*, 48: 121-123.

Kumar, K. V. A., R. Thomy, K. P. Deepa, M. Hashim and M. Sudhakar. 2016. Length weight relationship of six deep-sea fishes from the shelf regions of western Bay of Bengal and Andaman waters. *J. Appl. Ichthyol.*, 32: 1334-1336.

Kumar, K. V. A., R. Nikki, K. Oxona, M. Hashim and M. Sudhakar. 2017. Relationships between fish and otolith size of nine deep-sea fishes from the Andaman and Nicobar waters, North Indian Ocean. *J. Appl. Ichthyol.*, 33(6): 1187-1195.

Kumar, K. V. A., R. Thomy, M. Hashim and M. Sudhakar. 2018. Length-weight relationships of 11 deep-sea fishes from the western Bay of Bengal and Andaman waters, India. *J. Appl. Ichthyol*, 34(4): 1048-1051.

Kuriakose, S. 2014. Estimation of length weight relationship in fishes, Reprinted from the CMFRI, FRAD. Training Manual on Fish Stock Assessment and Management, 150 pp.

Le Cren, E. D. 1951. Length-weight relationship and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). *J. Anim. Ecol.*, 20: 201-219.

Mathialagan, R., R. Sivakumar, N. Rajasekaran and S. Chandrasekar. 2014. Length-frequency distribution and length-weight relationship of reba carp *Cirrhinus reba* (Hamilton, 1822 Cypriniformes: Cyprinidae) from Lower Anicut, Tamil Nadu, India. *Inter. J. Fish Aquat. Studies*, 2: 115-125.

Morato, T., P. Afonso, P. Loirinho, J. P. Barreiros, R. S. Sanstos and R. D. M. Nash. 2001. Length-weight relationships for 21 costal fish species of the Azores, North-eastern Atlantic. *Fish. Res.*, 50: 297-302.

Nair, R. V. and K. K. Appukuttan. 1973. Observations on the food of deep sea sharks *Halaeurus hispidus* (Alcock), *Eridacnis radcliffei* Smith and *Iago omanensis* Compagno and Springer. *Indian J. Fish.,* 20(2): 575-583.

Ogle, D. 2013. FishR Vignette-Length-Weight relationships. *Fish. Res.*, 99: 244-247.

Orlov, A. and C. Binohlan. 2009. Length-weight relationships of deep-sea fishes from the western Bering Sea. *J. Appl. Ichthyol.*, 25(2): 223-227.

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. WorldFish. 8: 9-10.

Prokofiev, A. M., P. N. Psomadakis and O. Gon. 2020. A new deep-bodied species of Antigonia (Teleostei, Antigoniidae) from the Andaman Sea (northeastern Indian Ocean). *Zootaxa*, 4763(2): 213-216.

R Core Team. 2020. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Department of Environment, Fisheries and Marine Service, Ottawa, On. 382 pp.

Sileesh, M., B. M. Kurup and A. Korath. 2020a. Length at maturity and relationship between weight and total length of five deepsea fishes from the, Andaman and Nicobar Islands of India, North-eastern Indian Ocean. *J. Mar. Biol. Assoc. UK*, 100(4): 639-644.

Sileesh, M., B. M. Kurup and A. Korath. 2020b. Length-weight relationship of deep-sea demersal finfishes from the Southeastern Arabian Sea. *J. Appl. Ichthyol.*, 36(6): 855-857.

Spiegel, M. R. 1991. Theory of Statistics Applications. McGraw-Hill, Paris, 358 pp.

Sreedhar, U., G. V. S. Sudhakar and B. Meenakumari. 2013. Length weight relationship of deep-sea demersal fishes from the Indian EEZ. *Indian J. Fish.*, 60(3): 123-125.

Thomas, J., S. Venu and B. M. Kurup. 2003. Length-weight relationship of some deep-sea fish inhabiting the continental slope beyond 250 m depths along the West Coast of India. *Naga, the ICLARM Quarterly*, 26: 17-21.

Venkataramanujam, K. and N. Ramanathan. 1994. Length-weight relationship. In: Manual of Fish Biology (eds. K. Venkataramanujam, K. and N. Ramanathan), Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. p. 19-21.

Zar, J. H. 1999. Biostatistical analysis (4th ed.) Upper Saddle River, NJ: Prentice Hall. 931 pp.