Indian J. Fish., 71 (4): 27-32, 2024

doi:10.21077/ijf.2024.71.4.145746-04

Available online at: epubs.icar.org.in/index.php/IJF

Morphometric differentiation of bigeye scad *Selar crumenophthalmus* (Bloch, 1793) from South Konkan coast of Maharashtra by truss network analysis

Punam Bhole[1], Vivek Nirmale[1**], Ravindra Pawar[1], Shardul Gangan[1] and Santosh Metar[2]

[1]College of Fisheries, Shirgaon, Ratnagiri - 415 715, Maharashtra, India
[2]Marine Biological Research Station, Ratnagiri - 415 612, Maharashtra, India

Abstract

Stock discrimination of bigeye scad, *Selar crumenophthalmus* along the south Konkan coasts of Maharashtra using truss morphometry was attempted based on the study of 120 individuals collected from Harnai, Ratnagiri and Malvan coasts of the region. A nine point truss network with eighteen truss variables was studied. Truss morphometry showed significant differences in CC (2-3), DD (2-8), EE (2-9), FF (3-4), KK (4-6), LL (4-7) and NN (5-6) distances from the three sampling locations in 18 truss morphometric measurements. Truss morphometry being able to cover the entire body in uniform fashion proved to be a robust technique in discriminating the population of *S. crumenophthalmus* in three distinct stocks within south Konkan region.

*Correspondence e-mail:
viveknirmale416@gmail.com

Keywords:
Bigeye scad, Carangidae,
Stock differentiation, Truss morphometry

Received : 28.11.2023
Accepted : 23.12.2024

Introduction

Family Carangidae includes highly diverse groups of important food fishes such as jacks, pompanos, trevallies, scads and amberjacks. About 153 species of carangids belonging to 39 genera have been reported from the seas around the world (Fricke *et al*., 2024). Carangids can be found in all tropical as well as sub-tropical marine areas worldwide (Vaniz *et al*., 1999). They are extensively spread in the Atlantic, Pacific and Indian Ocean (Kasim, 2003). About 62 species from 20 genera have been reported from Indian waters (Abdussamad, 2007). Carangids possess either one or combination of characters like detached anal spine, lateral line scutes, fleshy caudal keel, and dorsal as well as ventral grooves on caudal peduncle (Fischer and Bianchi, 1984). Carangids are caught by variety of gears such purse seine, trawl net, shore seine, ring seine, drift net, bottom set gillnets as well as hook and lines (Shetkar and Nirmale, 2023). In India, total carangid production stood at 2.4 lakh t contributing about 4.9% of the total marine fish production. Carangids are marketed as fresh, salted, or dried (Smith-Vaniz, 1984). Bigeye scads are commonly used as live bait for tuna and other large pelagic fish caught in association with fish aggregating devices (FADs) (Biais and Taquet, 1992).

The bigeye scad *Selar crumenophthalmus* (Bloch, 1793) is mainly found in marine reef-associated areas in a depth range of up to 170 m (Smith-Vaniz, 1984) but usually at 2 to 10 m depth (Gasparina and Floeter, 2001). Occasionally, they are also found in turbid waters (Smith-Vaniz, 1984). The species is characterised by fusiform, elongated and compressed body. The dorsal head profile is more or less straight; mouth terminal; large eye shorter than snout length; adipose eyelid well developed, covering the eye almost entirely; scales on lateral line 90-91; two dorsal fins with 24-27 soft rays; caudal fin forked; two anal fins with 3 spines each and 21-23 soft rays; pelvic fin situated in thoracic position (Randall *et al*., 1990).

For effective fishery management and stock rebuilding programs, knowledge of stock structure, distribution of fishing effort and mortality among the various components are essential since each stock must be managed separately to optimise their yield (Carvalho and Hauser, 1995; Begg *et al*., 1999). The main purpose of truss morphometrics is to analyse the shape and size of the organism with the help of statistical methods. Morphometric analysis gives information on phenotypic stocks, or groupings that have comparable rates of growth, mortality and reproduction (Booke, 1981) and has been recognised as a powerful and essential basis for evaluating the population structure and as basis for identifying stocks among the species (Ihssen *et al*., 1981). In the above context, the present study was undertaken to investigate the stock structure of *S. crumenophthalmus* from the south Konkan coast of Maharashtra based on morphometric characteristics using truss morphometry.

Materials and methods

The present study was carried out in two coastal districts of Maharashtra namely Ratnagiri and Sindhudurg representing the south Konkan coast. Geographically the study area is located between 17°02'43"N and 73°16'57"E to 15°43'46"N and 73°40'37"E (Fig. 1). The south Konkan coast has a coastline of 281 km and a continental shelf area of 52000 km ^{2}. Sampling was carried out from three landing centres *viz.,* Harnai, Ratnagiri and Malvan of south Konkan situated along the Anjarle, Mirya and Sarjekot estuaries respectively during December 2022 to October 2023.

Sample collection

A total of 120 specimens of *S. crumenophthalmus* ranging in size from 18.79-26.4 cm total length (TL) were sampled for the study. Forty samples were collected from each landing centre. Size of the specimens from Harnai varied from 18.7 to 21.9 cm TL, while size of the individuals from Ratnagiri ranged from 19.05 to 22.3 cm TL and those from Malvan varied between 21.2 and 26.4 cm TL. The samples comprised of pooled individuals. No sexual dimorphism was observed in the collected individuals. No juveniles were included in the morphometric analysis. The individuals were placed in insulated ice box with ice and bought to the laboratory. The samples were cleaned thoroughly in running water to remove slime or dirt and stored temporarily in a freezer at -20°C. The frozen samples were thawed adequately before further analysis.

Digitisation of samples

Each fish was mounted on a thick graph paper on its left side and given a specific code for identification. Digital photographs of each specimen were taken with Canon Coolpix B 500 point and shoot camera (image resolution 20.1 megapixels).

Extracting truss morphometric data from digitised images

The landmarks used for extracting truss measurements from the body are given in (Fig. 2). The truss network was developed by interconnecting 9 landmarks leading to 18 truss measurements from each individual (Fig. 3). The truss morphometric data was extracted from each digitised image of the specimen by a combination of three softwares *viz.,* tpsUtil V1.69 (Rohlf, 2015), tpsDig2 V2.26 (Rohlf, 2015) and Paleontological statistics (PAST) (Hammer *et al*., 2001).

All the images were first converted from JPEG (*. jpeg) to TPS (*. tps) format by using a utility program called tpsUtil V1.69 (Rohlf, 2015) and ordered into a single file. The input of the image as TPS format is a prerequisite for the tpsDig2 programme to analyse and extract the morphometric data. The landmarks were digitised on the image using the 'digitised landmark' mode of the software and the landmark data was encrypted into the TPS files X-Y coordinates. The data encrypted TPS format image files were used as an input in the

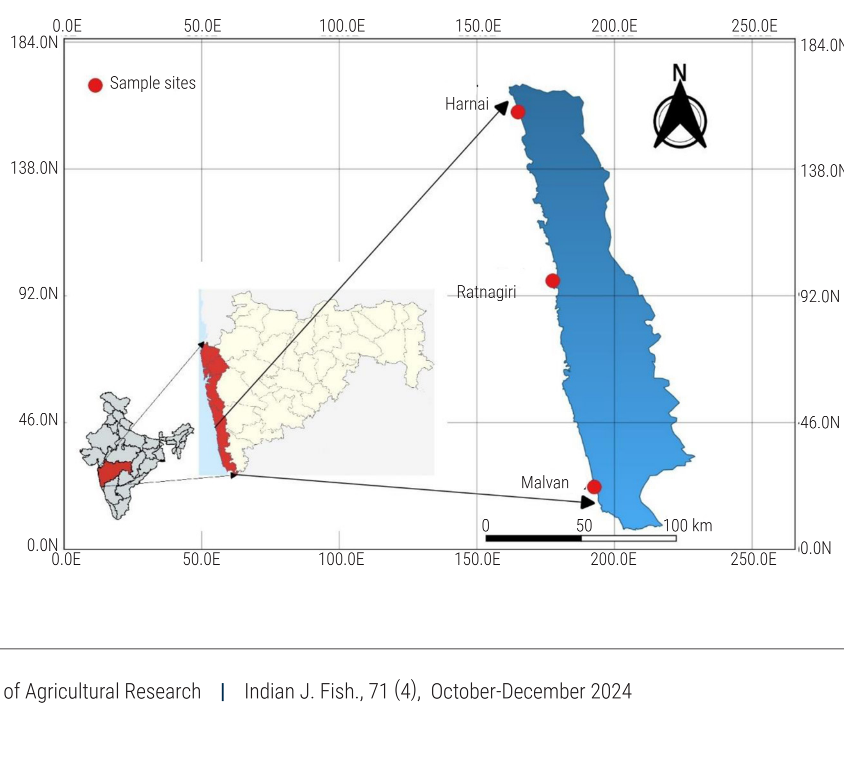


Fig. 1. Study locale

Fig. 2. Image of *S, crumenophthalmus* showing the 9 landmarks

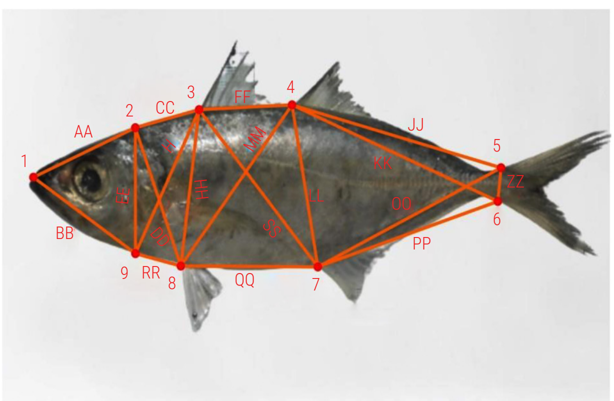


Fig. 3. Truss network of *S. crumenophthalmus*

PAST. The data on distances between the landmarks were extracted using the 'all distances from landmark' and '2 dimensional' options of the 'Geomet' menu.

Statistical analyses of truss morphometric data

Multivariate analysis of variance (MANOVA) and classification accuracy were used in the statistical analysis of truss morphometric data. Prior to MANOVA, the data were standardised by transforming each measurement to a proportion of the total length of the individual to remove bias of size differences and making inter-landmark measurements directly comparable among individuals (Canty *et al*., 2018). MANOVA was performed for 18 truss morphometric measurements to test the significant differences at different locations by using SAS 9.3. The classification accuracy was evaluated based on percentage of individuals correctly assigned into original sampling location and then calculating the proportion of correctly allocated individuals.

Results

Truss morphometric data

Multivariate analysis of variance (MANOVA)

A 9-point truss network was created to get 18 morphometric measurements which have been used for truss network analysis in the present study. Eighteen standardised data truss morphometric measurements were selected (Table 1). Among the truss morphometric measurements, seven measurements *i.e.* CC (2-3), DD (2-8), EE (2-9), FF (3-4), KK (4-6), LL (4-7) and NN (5-6) were significantly different ($p<0.05$) among the three sampling locations. The comparison between Harnai and Ratnagiri populations showed significant difference ($p<0.05$) in nine truss morphometric measurements namely FF (3-4), GG (3-7), HH (3-8), LL (4-7), MM (4-8), PP (6-7), OO (5-7), QQ (7-8) and NN (5-6) (Fig. 4a). The comparison between Ratnagiri and Malvan populations showed significant difference ($p<0.05$) in eight truss morphometric measurements namely AA (1-2), BB (1-9), CC (2-3), EE (2-9), KK (4-6), LL (4-7), OO (5-7) and NN (5-6) (Fig. 4b). The comparison between Harnai and Malvan populations showed significant difference ($p<0.05$) in seven truss morphometric measurements namely BB (1-9), CC (2-3), DD (2-8), EE (2-9), HH (3-8), II (3-9) and RR (8-9) (Fig. 4c). The results of group classification showed that 95, 97.6 and 97.5% individuals were correctly classified from Ratnagiri, Malvan and Harnai respectively (Table 2).

Discussion

Truss morphometric data

Multivariate analysis of variance (MANOVA)

Strauss and Bookstein (1982) proposed obtaining linear distances across the fish' body by creating a box-truss network between landmarks covering the entire body. Several researchers compared the overall performance of traditionally measured finfish dimensions to such box-truss distances and observed that trussed data resulted in more accurate classification of individuals (Strauss and Bookstein, 1982; Winans, 1987; Schweigert, 1990; Roby *et al.*, 1991). A total of 9 truss landmarks yielding 18 morphometric measurements were used for truss morphometrics in the present study. They include: AA (1-2), BB (1-9), CC (2-3), DD (2-8), EE (2-9), FF (3-4), GG (3-7), HH (3-8), II (3-9), JJ (4- 5), KK (4-6), LL (4-7), MM (4-8), NN (5-6), OO (5-7), PP (6-7), QQ (7-8), and RR (8-9). MANOVA performed on truss data yielded significant results based on Wilk's Lambda and Pillai's Trace ($p<0.05$), demonstrating significant differences in the stocks from all three locations. Among the 18 truss measurements, seven measurements *i.e.* CC (2-3), DD (2-8), EE (2-9), FF (3-4), KK (4-6), LL (4-7) and NN (5-6) differed significantly ($p<0.05$) across the three sampling locations.

The Ratnagiri and Malvan populations differ significantly ($p<0.05$) in eight measurements namely AA (1-2), BB (1-9), CC (2-3), EE (2-9), KK (4-6), LL (4-7), OO (5-7) and NN (5-6). Briefly, distance AA (1- 2) represents the snout up to the head region. BB (1-9) represents the

Table 1. MANOVA for standardised data on truss morphometric measurements (different superscripts indicate significant differences based on MANOVA followed by Tukey's HSD test; p value

			Sampling locations			MANOVA			
S. No.	Landmarks	Distance	Ratnagiri	Malvan	Harnai	Wilks' Lambda		Pillai's Trace	
				Mean		F ratio	p-value	F ratio	p- value
1	1-2	AA	0.160419	0.165005	0.166549				
2	1-9	BB	0.224119	0.235706	0.223491				
3	2-3	CC	0.154594	0.159898	0.147632				
4	2-8	DD	0.244941	0.253209	0.238106				
5	2-9	EE	0.199487	0.203693	0.196948				
6	3-4	FF	0.159339	0.16426	0.148752				
7	3-7	GG	0.321478	0.322445	0.313991				
8	3-8	HH	0.249478	0.247757	0.240448				
9	3-9	II	0.255369	0.253484	0.250044				
10	4-5	JJ	0.366243	0.362997	0.360136	3.147	< 0.05	4.72	< 0.05
11	4-6	KK	0.382975	0.375727	0.368404				
12	4-7	LL	0.25997	0.252328	0.247956				
13	4-8	MM	0.317362	0.316511	0.306576				
14	5-6	NN	0.052469	0.043126	0.041143				
15	5-7	OO	0.347793	0.332189	0.334634				
16	6-7	PP	0.326756	0.314129	0.314133				
17	7-8	QQ	0.233489	0.240875	0.240464				
18	8-9	RR	0.082978	0.086613	0.082626				

Table 2. Classification accuracy (%)

		Sampling locations		
		Ratnagiri	Malvan	Harnai
Truss morphometric	Correct	95%	97.6%	97.5%
	Wrong	5%	2.4%	2.5%

ventral side of the body. CC (2-3) represents the head region to the origin of the first dorsal fin. EE (2-9) represents the vertical distance on the anterior side of the body. KK (4-6) represents the posterior side of the body. LL (4-7) represents the vertical distance on the posterior side of the body. OO (5-7) represents the distance from the anal fin to the caudal peduncle region and NN (5-6) represents the vertical distance of the caudal peduncle.

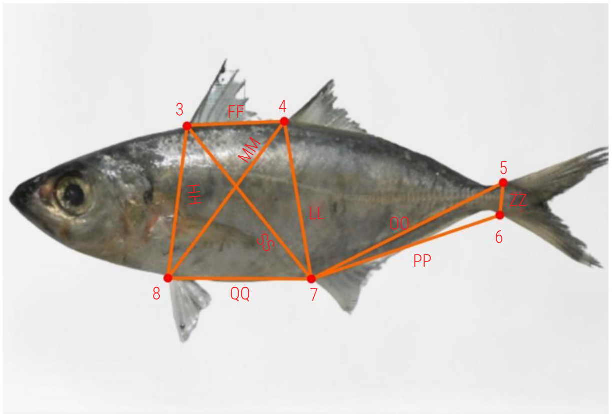
Comparisons between Harnai and Malvan populations showed significant differences ($p < 0.05$) in the seven truss measurements namely BB (1-9), CC (2-3), DD (2-8), EE (2-9), HH (3-8), II (3-9) and RR (8-9). Briefly, distance BB (1-9) represents the ventral side of the body. CC (2-3) represents the head region to the origin of the first dorsal fin. DD (2-8) represents vertical distance on the anterior side of the body. EE (2-9) represents the vertical distance on the anterior side of the body, while RR (8-9) represents the ventral side of the body.

The comparison between Harnai and Ratnagiri populations showed significant difference ($p<0.05$) in nine truss morphometric measurements namely FF (3-4), GG (3-7), HH (3-8), LL (4-7), MM (4-8), PP (6-7), OO (5-7), QQ (7-8) and NN (5-6). Distance FF (3-4) represents the first dorsal fin base length. GG (3-7) represents the distance of the middle portion of the body. HH (3-8) represents the vertical distance on the anterior side of the body. LL (4-7) represents the vertical distance on the posterior side of the body. PP (6-7) is the distance from the anal fin's origin to the caudal peduncle area. QQ (7-8) represents the horizontal distance of the ventral part of the body and NN (5-6) represents the vertical distance of the caudal peduncle.

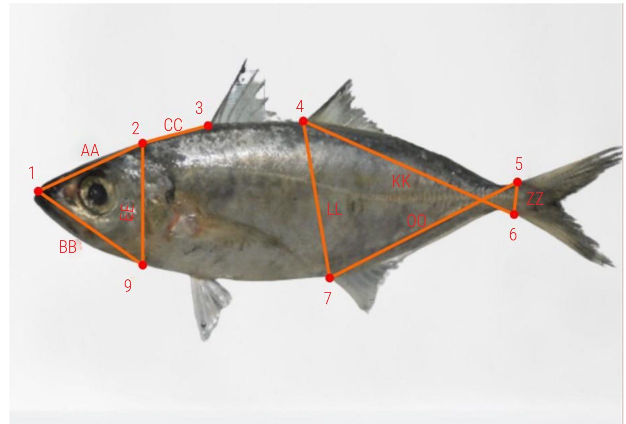
Truss analysis indicated significant phenotypic heterogeneity among populations of *S. crumenophthalmus* from the south Konkan coast of Maharashtra and at a very small spatial resolution from 92 km in Harnai to Ratnagiri and 106 km from Ratnagiri to Malvan and 198 km from Harnai to Malvan. Similarly, Canty *et al*. (2018) reported the highest accuracy in morphometric techniques (79.5%) at small spatial scales of 5-60 km.

Differences in morphometric characters might be related to several environmental variables which influence the fish morphology, including diet (Wimberger, 1992; Tonn *et al*., 1994; Olsson *et al*., 2006; Cadrin *et al*., 2014), water temperature (Lohmus, Sundstrom, Bjorklund and Devlin, 2010), predation pressure (Scharnweber *et al*., 2013), habitat structure (Willis *et al*., 2005), depth (Mwanja *et al*., 2011) and water currents (Franssen *et al*., 2013). Local hydrology can also be a driving force of morphometric differences as variations in environmental and behavioural factors can be reflected in changes in body forms and shapes (Webb, 1984). The causes of truss morphological variations across locations are sometimes difficult to explain. However, it is widely known that morphometric characters may respond to environmental circumstances with a high degree of plasticity (Wimberger, 1992). Such interactions include competition for food, space and shelter, predation pressure and hydrobiological conditions such as water temperature and salinity (Rawat *et al*., 2019).

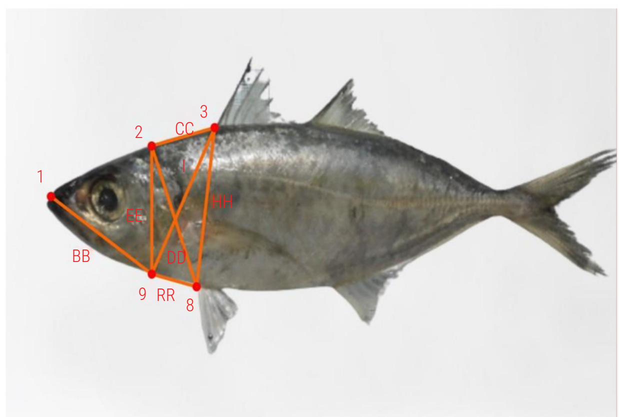
Ecological and evolutionary processes cause changes in the morphological characteristics of the fish population. Variation in populations refers to differences in behavioural, morphological, or life cycle characteristics and it is most often observed in vertebrate



(a)



(b)



(c)

Fig. 4. (a) Harnai - Ratnagiri stocks, (b) Ratnagiri - Malvan stocks and (c) Harnai - Malvan stocks

populations (Wimberger, 1992; Robinson and Wilson, 1994; Smith and Skulason, 1996).

In the present study, the populations of *S. crumenophthalmus* were sampled from South Konkan coast having an approximate coastline of 200 km. It is unlikely that ecological interactions and hydrobiological parameters, including temperature and salinity, differ significantly within this limited range. The results thus prove the efficiency or power of truss morphometrics in discriminating populations at small spatial scales and short geographic distributional ranges. Applicability and efficiency of truss analysis in delineating fish populations at a smaller spatial scale are in agreement with Canty *et al.* (2018).

However, further research needs to be carried out on investigating the role of diet, predation pressure, habitat structure and water current in affecting the morphometric characteristics of *S. crumenophthalmus* population along the south Konkan coast.

Classification accuracy

The classification accuracies for Ratnagiri, Malvan and Harnai were 95, 97.6 and 97.50% respectively. The percentages of correct classification recorded from the three locations were very high compared to the accuracy based on conventional morphometrics. In a way, this further validates the usefulness of truss morphometrics in stock discrimination.

In the present study, the truss network analysis proved to be a powerful tool in delineating the population of *S. crumenopthalmus* into three distinct stocks at a small spatial scale along the South Konkan coast of Maharashtra. The truss network gave better data acquisition and a wider range of analysis tools. However, the present study did not clearly depict where the boundaries between the truss differences lie.

Acknowledgements

The authors are grateful to the Associate Dean, College of Fisheries, Shirgaon, Ratnagiri for providing facilities to carry out the research at Department of Fisheries Biology.

References

Abdussamad, E. M., Prathibha, R. and Mohamed, O. M. M. J. H. 2007. A field identification key for 20 genera of family Carangidae. *J. Mar. Biol. Ass. India*, 49(2): 141-147.

Anon. 2023. *Handbook on fisheries statistics*. Department of Agriculture and Co-operation,, Ministry of Agriculture, Government of India, New Delhi, 153 p.

Biais, G. and Taquet, M. 1992. Local fishing aroung Reunion. *Reperes Ocean*, 2: 78 p. (In French)

Book, H. E. 1981. The conundrum of the stock concept-are nature and nurture definable in fishery science. *Canadian J. Fish. Aquat. Sci.*, 38(12): 1479-1480. https://doi.org/10.1139/f81-200.

Canty, S. W., Truelove, N. K., Preziosi, R. F., Chenery, S., Horstwood, M. A., and Box, S. J. 2018. Evaluating tools for the spatial management of fisheries. *J. Appl. Ecol.*, 55(6): 2997-3004.

Carvalho, G. R. and Hauser, L. 1995. Molecular genetics and the stock concept in fisheries. In: Carvalho, G. R. and Pitcher, T. J. (Eds.), *Molecular genetics in fisheries*. Chapman and Hall, London, UK, pp. 55-79.

Fischer, W. and Bianchi, G. 1984. *FAO species identification sheets for fishery purposes. Western Indian Ocean; Fishing Area 51*. Food and Agricultural Organisation of the United Nations, Rome, Italy.

Franssen, N. R., Stewart, L. K., and Schaefer, J. F. 2013. Morphological divergence and flow-induced phenotypic plasticity in a native fish from anthropogenically altered stream habitats. *Ecology and Evolution*, 3(14): 4648-4657. https://doi.org/10.1002/ece3.842.

Fricke, R., Eschmeyer, W. N. and van der Laan, R. 2024. *Eschmeyer's catalogue of fishes: Species, references*. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp (Accessed 16 December 2024).

Ihassen, P. E., Evans, D. O., Christie, W. J., Reckahn, J. A. and Desjardine, R. L. 1981. Life history, morphology, and electrophoretic characteristics of five allopatric stocks of lake whitefish in the Great Lakes region. *Canadian J. Fish. Aqua.Sci.*, 38(12): 1790-1807. https://doi.org/10.1139/f81-226.

Kasim, H. M. 2003. Carangids. In: Joseph, M. M. and Jayaprakash, A. A. (Eds.), *Status of exploited marine fishery resources of India*. ICAR-Central Marine Fisheries Research Institute, Kochi, India, pp. 66-75.

Lohmus, M., Sundström, L. F., Björklund, M. and Devlin, R. H. 2010. Genotype-temperature interaction in the regulation of development, growth, and morphometrics in wild-type and growth-hormone transgenic coho salmon. *PLoS One*, 5(4): e9980. https://doi.org/10.1371/journal.pone.0009980.

Mwanja, M. T., Muwanika, V., Nyakaana, S., Masembe, C., Mbabazi, D., Rutasire, J. and Mwanja, W. W. 2011. Population morphological variation of the Nile perch (*Lates niloticus*, L. 1758), of East African Lakes and their associated waters. *African J. Environ. Sci. Technol.*, 5(11): 941-949. https://doi.org/10.5897/AJEST11.197.

Rawat, S., Benakappa, S., Pazhayamadom, D. G., Kumar, J., Soman, C., and Venugopal, R. 2019. Stock structure analysis of Splendid ponyfish *Eubleekeria splendens* (Cuvier, 1829) along Indian coast using truss network system. *Indian J. Geo. Mar. Sci.,* 49(4): 434-443.

Robinson, B. W., and Wilson, D. S. 1994. Character release and displacement in fishes: A neglected literature. *The American Naturalist*, 144(4): 596-627.

Rohlf, F. J. 2015. The TPS series of software. *Hystrix*, 26(1): 9-12.

Shetkar, M. B. and Nirmale, V. H. 2023. A review of food and feeding habits of carangids occurring along the Indian coast. *J. Ind. Fish. Assoc.*, 50(3): 89-97.

Smith, T. B. and Skulason, S. 1996. Evolutionary significance of resource polymorphisms in fishes, amphibians, and birds. *Ann. Rev. Ecol. Sys.*, 27(1): 111-133. https://doi.org/10.1146/annurev.ecolsys.27.1.111.

Smith-Vaniz, W. F. 1984. Carangidae. In Fischer, W. and Bianchi, G. (Eds.), *FAO species Identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol. 1.* Food and Agricultural Organisation of the United Nations, Rome, Italy.

Strauss, R. E., and Bookstein, F. L. 1982. The truss: body form reconstructions in morphometrics. *Sys. Biol.*, 31(2): 113-135. https://doi.org/10.1093/sysbio/31.2.113.

Tonn, W. M., Paszkowski, C. A. and Holopainen, I. J. 1994. Ecology of fish and fishes in small boreal forest lakes: A review. *Hydrobiologia*, 291(1-3): 173-187.

Webb, P. W. 1984. Body form, locomotion and foraging in aquatic vertebrates. *American Zoologist*, 24(1): 107-120. https://doi.org/10.1093/icb/ 24.1.107.

Wimberger, P. H. 1992. Plasticity of fish body shape. The effects of diet, development, family and age in two species of Geophagus (Pisces: Cichlidae). *Biol. J. . Linn. Soc.*, 45(3): 197-218.

Winans, G. A. 1987. Using morphometric and meristic characters for identifying stocks of fish. *American Fisheries Society Symposium*, 1: 47-62.