Available online at: www.mbai.org.in doi:10.6024/jmbai.2021.63.2.2176-05

Morphometric variations associated with breeding season in obtuse barracuda, *Sphyraena obtusata* Cuvier, 1829 observed from the commercial fish landings at Vizhinjam, Kerala, India

R. Shaila Prasad[2]*, B. Santhosh[1], Kurian Mathew Abraham[2], S. Jasmine[1], S. Surya[1], K. N. Saleela[1] and A. Udayakumar[1]

[1]Regional Centre of ICAR- CMFRI, Vizhinjam, Thiruvananthapuram -695 521, Kerala, India.
[2]University of Kerala, Kariavattom, Thiruvananthapuram-695 581, Kerala, India.

*Correspondence e-mail: shailaprasad3@gmail.com

Original Article

Received: 10 April 2020 Accepted: 10 July 2021 Published: 15 Sep 2021

Abstract

Obtuse barracuda (*Sphyraena obtusata* Cuvier, 1829) is one of the common species available throughout the year in the landings from traditional fishing crafts and contribute much to the total landings along Thiruvananthapuram coast, Kerala. Since all size groups are available throughout, the present study was carried out to find out the morphometric variations of the species with respect to its breeding season. A total of 9 morphometric variables and weight were recorded monthly from 429 fishes, landed at Vizhinjam fish landing center (Thiruvananthapuram District, Kerala) for two years from January 2017 to December 2018. Analysis of variance (One Way ANOVA) along with post hoc comparisons (DMR test) of the morphometric variables comparing breeding seasons (pre spawning, spawning and post spawning) revealed significant ($P < 0.05$) variations in weight, head length, snout length, snout to pre-nostril length, inter-dorsal length and caudal peduncle length in total population (N=429). Seasonal comparison of male population (n=176) alone also showed significant difference similar to total population except head length and female population (n=253) registered significant difference in only three variables (snout length, snout to pre-dorsal length and caudal peduncle length). Morphometric ratios (TL: SL, SnL: SL, Sn-Plvc: SL, Intr-Drsl: SL and CPL: SL) showed significant variations between the seasons. Principal component analysis extracted three variables ratio, TL: SL, SnL: SL and CPL: SL as contributing factors for morphometric variations in breeding season. Rate of growth in terms of morphometric ratios showed more fluctuations than measured variables, which clearly emphasized the shift in growth rate from length to weight dependency during breeding season.

Keywords: *Sphyraena obtusata, morphometry, morphometric ratios, spawning season, principal component analysis*

Introduction

Morphometric analysis reveal the differences in body shape and size between different individuals or groups to discriminate populations of the same species (Hirsch *et al.*, 2013), which may be useful for the conservation and management of fishery resources, identification and discrimination of variations within species like stock, gender etc. Minor growth or other variations within the population also can be delineated through morphometric analysis. During spawning season, both male and female fish show many morphometric differences due to dynamic changes associated with maturation and sexual dimorphism. A few reports also suggest that the reason for variation in the morphometric and meristic characters may range from variability in population growth under the influence of environmental parameters as well as the condition of fish

(Hubbs, 1921; Vladykov, 1934; McHugh, 1954; Allendorf *et al.*, 1987; Wimberger, 1992). Even though, all nine species of barracudas are important commercial species in Indian waters, only few reports are there about the morphometry, growth and biology of these species (Okera, 1982; Allam *et al.*, 2004; Hosseini *et al.*, 2009). Reports are there on length weight relationship of *S. obtusata* from southwest coast of India (Premalatha and Manojkumar, 1990) and also from Jaffna lagoon, Sri Lanka (Sivashanthini *et al.*, 2009).

The barracudas of the family Sphyraenidae, also known as sea-pikes are commercially important and one of the most demanded marine food fishes of tropical and subtropical Indo-Pacific region (Williams, 1959; Blaber, 1982). So far 29 valid species have been reported in the family and only nine species have been reported from Indian region (Eschmeyer and Fong, 2013). Among these, only five species, *Sphyraena obtusata, S. putnamae, S. forsteri, S. jello* and *S. barracuda* contributed to the fishery along Thiruvananthapuram coast of Kerala. Obtuse barracuda (*Sphyraena obtusata* Cuvier, 1829) is one of the common species of barracuda in the landings from traditional fishing crafts and contribute more to the total landings. The average annual landings of barracudas was 2057t and the catch rate of 5.2kg/unit, of which *S. obtusata* formed 45.3% of the total catch (CMFRI, 2018). Year round survey of the *S. obtusata* landings showed variations in quantity and size groups in different seasons. The size difference in landings may be due to difference in age groups, gender groups and maturity stages in the population. Gender based morphometric variations in the breeding season among the population (Modesto and Canario, 2003; Sisneros, 2009), also may contribute to size difference in the catch which ultimately influence the total landings. This information is vital for fisheries management, policy making and assessment of stock and fishery potential.

Growth, stock assessment and fishery of obtuse barracuda from Gulf of Mannar area was reported by Somvanshi (1989) and Kasim and Balasubramanian (1990). Jaiswar *et al.* (2004) studied the morphometric and meristic variables of obtuse barracuda *S. obtusata* from Mumbai (Bombay) waters and reported allometric relationship and high degree of homogeneity within the population.

Even though knowledge on morphological differences is crucial to contribute a better management plan and conservation strategies (Muchlisin *et al.*, 2014), no serious attempts have been made to delineate the morphometric variations during spawning season neither in barracudas nor in other similar groups of marine fishes. The morphometric variability induced due to changes occurred in the breeding season was not seriously dealt with for many species including barracudas. Present study describes the variations in morphometric characters in relation to the breeding season in obtuse barracuda, *S. obtusata* from the commercial fish landings of Vizhinjam coast, Kerala.

Material and methods

Fish samples were collected monthly from Vizhinjam landing centre (Lat. 18°22'30" N; Long. 76°59'15"E) Thiruvananthapuram, Kerala for two years from January 2017 to December 2018. Samples of *S. obtusata* were collected directly from the landings of boats which used different gears like boat seine, gill net, *roll net* and hooks and lines for their harvest. Fishes belong to all size groups were collected in fresh condition and transported to laboratory for further investigations. A total of 429 specimens of *S. obtusata* (176 males and 253 females) were examined for 9 morphometric variables and weight of which lengths (mm) were measured using a digital vernier caliper and weight (g) was measured using a precision electronic balance. In addition to the total weight (Wt), morphometric data like total length (TL), standard length (SL), head length (HL), snout length (SnL), snout to pre-nostril (Sn-PrNsrl), snout to pelvic (Sn-Plvc), snout to anal (Sn-Anl), inter-dorsal length (IntrDrsl) and caudal peduncle (CPL) length were measured. All the length variables were made in to ratios to the standard length (SL) as morphometric ratios for further statistical computations. After recording all morphometric measurements, fishes were examined for identification of its gender by dissection and microscopic observations were made to assess the maturity stages. Fishes were then categorized in to pre-spawning (immature and maturing or Stage 0 to 2), spawning (mature and ripe or Stage 3-4) and post-spawning (spent/Stage 5) group based on its maturity stage (Dharmamba, 1959; Premalatha and Manojkumar, 1990). To confirm and to corroborate the maturity stages with breeding season, gonado-somatic index (GSI; percentage of gonad weight to body weight) of female population were assessed. Analysis of variance (One Way ANOVA) was used to compare gender wise and pooled morphometric variables, weight and morphometric ratios between spawning seasons. Student's t test was employed to compare all variables between male and female of the sample population to distinguish sexual difference if any. Principal Component Analysis (PCA) was used to elucidate the morphometric ratios that influence the morphometric variations associated with spawning season. All statistical evaluations (Zar, 1996) were performed using the software R (R Core Team, 2020) and a probability value $p < 0.05$ was considered significant.

Results and discussion

Barracuda fishes have good consumer demand and the availability throughout year itself shows its stable stock, consistent recruitment and population sustainability in the Indian waters (Kasim and Balasubramanian, 1990). In general, breeding biology consider only the maturity stages, ovarian development studies, gonado-somatic index and size at first maturity for a species. This is true in the case of barracudas also (Okera, 1982; Allam *et al.*, 2004, Hosseini *et al.*, 2009). The size at first maturity is also a morphometric variable but it deals only with length groups in general or the particular length at 50% of the individuals attains maturity (Pauly, 1984). But breeding or the spawning season can be well defined by the condition of the fish, manifested through its morphometric characters.

Microscopic examination of gonads and ova along with the GSI (Fig. 1) of females revealed the breeding pattern which followed two well-defined breeding cycles in a year. The maximum percentages of fishes with ripe gonads were recorded during May and in September after a decline in June to August. Primarily gonad maturation started from April onwards and spent fishes started appearing from late September with maximum GSI as well as mature eggs were observed in September. Thus there were two peak periods of spawning observed in late May and September and the data on ova maturation, maturity assessment and GSI assessment were in tune with each other. Hence February to May was considered pre-spawning and October to January was considered post-spawning period. Premalatha and Manojkumar (1990) from southwest coast of India, Sivashanthini *et al.* (2009) from Sri Lankan coast and Allam *et al.* (2004) from Egyptian coast also reported the breeding season of the species as from July to October.

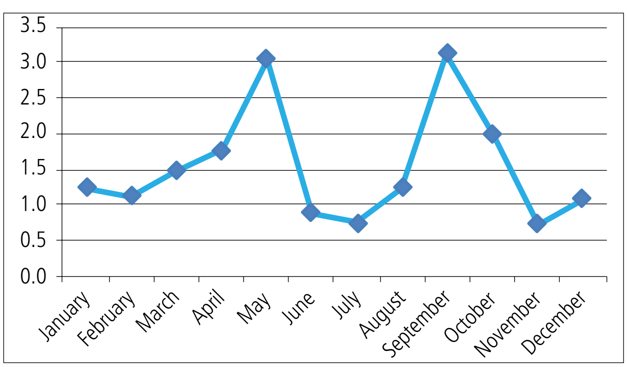

Fig. 1. Monthly mean GSI for female *S. obtusata* showing breeding seasons

All variables including morphometry of the sampled population were compared for three breeding seasons (pre-spawning, spawning and post-spawning) and between male and female revealed significant differences in many variables (Table 1). Weight registered significant ($P<0.01$) difference between breeding seasons with maximum weight and its variability recorded during spawning season, which have an influence on the morphometry and thereby shape and size of the species. Seasonal variation in length weight relationship was reported in *Harpadon nehereus* (Fofandi and Rohit, 2020). The difference in weight for male and female fishes in total population was not found significant, which indicate that the weight gain during spawning season may be proportional in both the sexes. The weight increment during spawning season is a normal phenomenon in both the sexes and is mainly due to gonadal development. Similar observations were also reported for *S. obtusata* by Somvanshi (1989) and Jaiswar *et al.* (2004) where increased landing by weight was recorded during the spawning season which has a commercial importance also as morphometric measurements and statistical relationships are imperative for both fishery biology (Mustafa and Brooks, 2008) and taxonomic studies. The total length (TL) and standard length (SL), neither gender wise nor total population wise registered significant difference among breeding seasons, which indicate that the weight increment is only due to gonadal development but not due to the growth. But total length registered a significant sexual difference with more size in females, which was prominent during spawning season.

Head length characteristics like snout length (SnL), snout to pre-nostril (Sn-PrNsrl) length along with head length of total population registered highly significant ($P<0.01$) difference between spawning seasons with gradual decrease from pre-spawning to post-spawning season. The head length difference in total population might be due to the cumulative effect of SnL and Sn-PrNsrl length fluctuation. It is imperative that SnL and Sn-PrNsrl differs significantly with maximum length during pre-spawning season. The reduction in SnL and Sn-PrNsrl may be due to fat deposition along the cephalic region along with reduction in feeding activity during spawning period. Allam *et al.* (2004) also reported similar observations in barracudas. These parameters were identical in both sexes. But head length registered a significant ($P<0.05$) difference between male and female, which may be due to the bulkiness attained in female fishes associated with gonad development along with the difference in total length between sexes. Body measurements like snout to pelvic (Sn-Plvc) and snout to anal (Sn-Anl) lengths did not registered any significant difference with respect to breeding season, whereas inter dorsal (IntrDrsl) length and caudal peduncle length (CPL) registered highly significant ($P<0.01$) difference among breeding seasons but male population alone did not showed difference in IntrDrsl and CPL. This morphometric variation can be attributed strongly with breeding season related size increment especially in female population. Even though seasonal changes were evident, gender differences were not evident for these parameters and Prasad *et al.* (2021) made similar observations in *S. obtusata* from south west coast of Kerala.

All morphometric variables along with weight showed variation with high dispersion values and ratios with standard measurements or transformed values gave much better information on size/morphometric variation including growth pattern. Length and weight showed more fluctuations than

Table 1. Analysis of variance (One Way ANOVA) of different parameters comparing breeding season of *S. obtusata*

Variables		Total population		Male		Female		t value (Comparing gender)
	Breeding Season	Mean	± SD	Mean	± SD	Mean	± SD	
Weight (Wt in g)	Pre-spawning	57.85	14.84	55.72	13.70	59.12	15.41	
	Spawning	66.03	31.52	66.05	32.94	66.01	30.76	-1.712
	Post-spawning	55.83	22.53	51.53	21.23	59.91	23.14	
	F value	7.178**	5.631**	2.29				
Total Length (TL in mm)	Pre-spawning	213.65	18.18	210.14	16.83	215.75	18.70	
	Spawning	214.96	38.41	212.75	40.85	216.40	36.92	-2.234
	Post-spawning	207.80	25.21	203.64	22.67	211.74	27.01	
	F value	2.283	1.548	0.543				
Standard Length (SL in mm)	Pre-spawning	176.23	14.60	173.67	13.79	177.77	14.91	
	Spawning	178.52	32.27	177.24	34.59	179.35	30.86	-1.738
	Post-spawning	173.34	21.23	170.75	19.58	175.79	22.57	
	F value	1.541	1.031	0.411				
Head Length (HL in mm)	Pre-spawning	60.72	4.69	59.74	4.84	61.30	4.51	
	Spawning	61.75	9.74	61.38	10.08	61.99	9.57	-2.124*
	Post-spawning	59.62	7.31	58.49	6.86	60.70	7.61	
	F value	2.627*	2.095	0.561				
Snout Length (SnL in mm)	Pre-spawning	26.82	8.29	26.80	9.12	26.82	7.80	
	Spawning	25.01	5.40	24.85	4.25	25.11	6.05	-1.042
	Post-spawning	23.99	3.31	23.28	2.45	24.66	3.85	
	F value	7.329**	4.954**	2.725*				
Snout to Pre-Nostril Length (Sn-PrNsrl in mm)	Pre-spawning	19.69	2.29	19.38	2.10	19.88	2.39	
	Spawning	19.22	3.10	19.11	2.95	19.30	3.21	-1.527
	Post-spawning	18.02	2.93	17.95	2.24	18.09	3.48	
	F value	12.956**	5.599**	7.035**				
Snout to Pelvic Length (Sn-Plvc in mm)	Pre-spawning	72.37	7.25	70.84	7.18	73.28	7.17	
	Spawning	72.64	12.96	72.71	13.12	72.59	12.94	-0.822
	Post-spawning	73.37	17.99	73.05	21.19	73.67	14.49	
	F value	0.216	0.409	0.172				
Snout to Anal Length (Sn-Anl in mm)	Pre-spawning	127.54	13.22	124.64	13.82	129.27	12.59	
	Spawning	128.69	23.74	128.10	24.38	129.07	23.45	-2.210*
	Post-spawning	123.80	16.96	121.07	15.52	126.40	17.97	
	F value	2.419	2.042	0.533				
Inter-Dorsal Length (IntrSrsl in mm)	Pre-spawning	25.03	5.11	24.77	5.40	25.19	4.95	-0.471
	Spawning	26.33	5.75	26.83	5.72	26.02	5.78	
	Post-spawning	24.28	4.10	23.83	4.33	24.71	3.85	
	F value	5.379**	4.799**	1.276				
Caudal Peduncle Length (CPL in mm)	Pre-spawning	32.74	4.41	32.32	4.27	33.00	4.50	
	Spawning	34.63	6.42	34.41	6.85	34.77	6.16	-0.984
	Post-spawning	33.14	3.78	32.96	3.88	33.31	3.70	
	F value	5.821**	2.588	3.228*				

* $P < 0.05$; ** $P < 0.01$

absolute morphometric variables, which clearly emphasizes the growth pattern shift from length to weight during breeding season. All variables except weight were converted in to ratio to the standard length and compared for the spawning season variability (Table 2), which also showed similar pattern of variability given by the absolute values. TL, SnL, Sn-PrNsrl, Sn-Plvc, IntrDrsl and CPL ratios to SL registered significant difference among spawning season of *S. obtusata*. These measurements when compared with respect to male and female groups separately also showed similar pattern of difference in breeding seasons. Since the ratio with SL showed difference, breeding season definitely change the morphometric pattern with a shift from normal growth to weight increment and thereby causing size bulkiness, which may be reduced later during post-spawning season.

Since six parameters among the ten variables under consideration registered significant difference in breeding season, principal component analysis (PCA) was performed with morphometric ratios of total population (Fig. 2) to elucidate the primary factors that affect the breeding season induced morphometric variations. HL to SL ratio appeared as principal component 1 (PC 1) with factor loading value of 0.869 (Eigen value 3.685; 46.06% variance) followed by TL to SL ratio as principal component 2 (PC 2) with factor loading value of 0.849 (Eigen value 1.688; 21.11% variance) and SnL to SL ratio as principal component 3 (PC 3) with factor loading value of 0.665 (Eigen value 0.814;

Table 2. Analysis of variance (One Way ANOVA) of different morphometric ratios comparing breeding season of *S. obtusata*

Parameter	Group	Total population		Male		Female	
		Mean	+ SD	Mean	+ SD	Mean	+ SD
TL:SL	Pre-spawning	1.212	0.025	1.210	0.021	1.214	0.027
	Spawning	1.205	0.021	1.201	0.026	1.207	0.018
	Post-spawning	1.199	0.029	1.194	0.035	1.204	0.021
	F value	10.003**	5.179**	3.971*			
HL:SL	Pre-spawning	0.345	0.011	0.344	0.011	0.345	0.012
	Spawning	0.348	0.024	0.349	0.035	0.347	0.014
	Post-spawning	0.344	0.012	0.343	0.012	0.346	0.011
	F value	2.061	1.489	0.712			
SnL : SL	Pre-spawning	0.153	0.051	0.155	0.055	0.152	0.049
	Spawning	0.141	0.023	0.142	0.017	0.140	0.025
	Post-spawning	0.139	0.012	0.138	0.012	0.140	0.011
	F value	7.415**	3.949*	3.623*			
Sn-PrNsrl : SL	Pre-spawning	0.112	0.011	0.112	0.013	0.112	0.012
	Spawning	0.109	0.012	0.110	0.018	0.108	0.008
	Post-spawning	0.105	0.013	0.106	0.009	0.104	0.017
	F value	12.203**	3.957**	9.092**			
Sn-Plvc:SL	Pre-spawning	0.410	0.020	0.407	0.023	0.412	0.018
	Spawning	0.408	0.031	0.413	0.040	0.406	0.023
	Post-spawning	0.421	0.070	0.424	0.086	0.418	0.050
	F value	3.041*	1.335	2.937*			
Sn-Anl:SL	Pre-spawning	0.723	0.038	0.717	0.049	0.727	0.030
	Spawning	0.721	0.051	0.725	0.073	0.719	0.029
	Post-spawning	0.714	0.033	0.710	0.040	0.718	0.024
	F value	1.788	1.050	2.793			
IntrDrsl:SL	Pre-spawning	0.142	0.025	0.142	0.027	0.141	0.024
	Spawning	0.148	0.022	0.153	0.026	0.145	0.019
	Post-spawning	0.140	0.018	0.139	0.018	0.141	0.018
	F value	4.419*	4.751*	0.758			
CPL:SL	Pre-spawning	0.186	0.020	0.186	0.019	0.186	0.020
	Spawning	0.195	0.019	0.196	0.023	0.194	0.015
	Post-spawning	0.193	0.018	0.194	0.014	0.191	0.020
	F value	9.414**	4.389*	4.925**			

* $P < 0.05$; ** $P < 0.01$

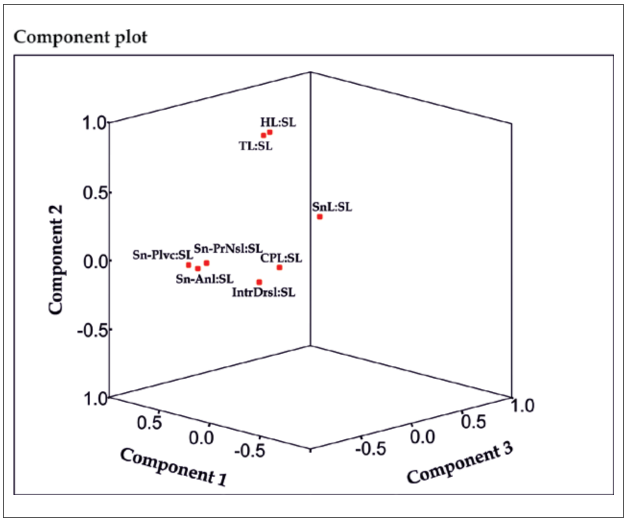

Fig. 2. Principal Component Analysis loading plot of morphometric ratios for breeding season of *S. obtusata*

10.17% variance). Since cephalometric variables like SnL and its related parameters showed much variation in the breeding season, PCA extracted HL as the PC 1 as combined effect of all the cephalometric variables especially the length from snout. The second and third factors, TL and SnL ratios to SL respectively also had significant contribution in morphometric growth pattern difference due to the breeding season. Even though, Jaiswar *et al.* (2004) reported morphometric and meristic variables of *S. obtusata*, no detailed report comparing the breeding season was available. A few reports on morphometric measurements analyzed using PCA for fish populations (Ihssen *et al.*, 1981; Surre *et al.*, 1986; Hedgecock *et al.*, 1989; Melvin *et al.*, 1992; Mamuris *et al.*, 1998; Trapani, 2003) are already there but all studies were concentrated on fish population or stock identification. Bijukumar *et al.* (2008) reported PCA to distinguish male and female population of sea horse. Comparatively, detailed morphometric evaluation of *S. obtusata* is lacking except for the report on the morphometric and meristic characters of *S. obtusata* from Mumbai coast (Maharashtra), by Jaiswar *et al.*, (2004).

Majority of the morphometric studies are for taxonomical purpose or stock assessment (King, 2007). Ayoade (2011) observed slight variation in meristic and morphometric features of *Schilbe mystus* from Asejire and Oyan Lakes from South-western Nigeria and reported that the variations reflected environmental differences. Fishes are very sensitive to environmental changes and quickly adapt themselves by changing necessary morphometric features (Hossain *et al.*, 2010), in relation to different ecological conditions also need to be evaluated further. It is a well-known fact that morphological characters can show high plasticity in response to differences in environmental conditions, such as food abundance and temperature (Allendorf and Phelps, 1988; Swain *et al.*, 1991; Wimberger, 1992).

Conclusions

Rate of growth in terms of morphometric ratios showed more fluctuations than absolute morphometric variables, which clearly emphasizes the growth rate shift from length to weight dependency during breeding season. Head length, total length and snout length were primary principal components contributing to spawning season induced morphometric variation in *S. obtusata* observed from landings at Vizhinjam, Thiruvananthapuram.

Acknowledgements

Authors acknowledge, Dr. A. Gopalakrishnan, Director, ICAR-CMFRI and Dr. M. K. Anil, Scientist-in-Charge, VRC of CMFRI for the facilities and encouragements. Authors express their sincere gratitude to the anonymous reviewer for critical suggestions for the improvement of the manuscript. First author acknowledges University of Kerala for the research fellowship.

References

Allam, S. M., S. N. Faltas and E. Ragheb. 2004. Reproductive biology of *Sphyraena* species in the Egyptian Mediterranean waters off Alexandria. *Egypt. J. Aquat. Res.,* 30(B): 255-270.

Allendorf, F. W. and S. R. Phelps. 1988. Loss of genetic variation in hatchery stock of cutthroat trout. *Trans. Am. Fish. Soc.*, 109: 537-543.

Allendorf, F. W., N. Ryman and F. Utter. 1987. *Genetics and fishery management: past, present and future in population genetics and fisheries management.* Seattle, WA & London: University of Washington press, p. 1-20.

Ayoade, A. A. 2011. Population characteristics of *Schilbe mystus* (Linne, 1758), from two different habitats: Asijare and Oyan lakes South Western Nigeria. *J. Fish. Aquat. Sci.,* 6(5): 571 - 577.

Bijukumar, A., Kurian Mathew Abraham and D. Soumya. 2008. Morphometry and Meristics of long nose seahorse, *Hippocampus trimaculatus* (Actinopterygii: Syngnathidae) from Kerala, South-west coast of India. *Acta Ichthyol. Piscat.*, 38(2): 149-156.

Blaber, S. J. M. 1982. The ecology of *Sphyraena barracuda* (Osteichthyes: Perciformes) in the Kosi system with notes on the Sphyraenidae of other Natal estuaries. *S. Afr. J. Zool.*, 17:171-176.

CMFRI, 2018. *Annual Report*, Central Marine Fisheries Research Institute, Kochi, Kerala, India.

Dharmamba, M. 1959. Studies on the maturation and spawning habits of some common clupeoids of Lawson›s Bay, Waltair. *Indian J. Fish.,* 6 (2): 374-388.

Eschmeyer, W. N. and J. D. Fong. 2013. *Species of fishes by family/subfamily.* http:// research.calacademy.org ichthyology/ catalog/family (Accessed 25 March 2013).

Fofandi, M. D. and P. Rohit, 2020. Seasonal variations in the length-weight relationship and relative condition factor of Bombay duck, *Harpadon nehereus* (Hamilton, 1822) (Aulopiformes: Synodontidae) inhabiting the marine area of the west coast of India. *Indian J. Geo Mar. Sci.*, 49(1): 1758-1763.

Hedgecock, D., E. Hutchinson, G. Li, F. Sly and K. Nelson. 1989. Genetic and morphometric variation in the Pacific sardine, *Sardinopssa gaxcaerulea*: comparisons and contrasts with historical data and with variability in the Northern anchovy, *Engraulis mordax. Fish. Bull.*, 87: 653-671.

Hirsch, P. E., R. Eckmann, C. Oppelt and J. Behrmann-Godel. 2013. Phenotypic and genetic divergence within a single whitefish form detecting the potential for future divergence. *Evol. Appl.*, 6(8): 1119 -1132.

Hossain, M. A. R., M. Nahiduzzaman, D. Saha, M. U. H. Khanam and M. S. Alam. 2010. Landmark based morphometric and meristic variations of the endangered carp, kalibaus *Labeo calbasu*, from stocks of two isolated rivers, the Jamuna and Halda, and a hatchery. *Zool. Stud.,* 49(4): 556-563.

Hosseini, S. A., S. Jamili, T. Valinassab, G. Vosoghi and S. M. R. Fatemi. 2009. Feeding and spawning of *Sphyraena jello* in the North-West of Persian Gulf. *J. Fish. Aquat. Sci.*, 4(1): 57-62.

Hubbs, C. L. 1921. Geographic variation of *Notemigonus crysoleucas* on American minnows. *Trans. Illinois St. Acad. Sci.,* 1018:147-151.

Ihssen, P. E., H. E. Booke, J. M. Casselman, J. M. McGlade, N. R. Payne and F. M. Utter. 1981. Stock identification: materials and methods. *Can. J. Fish. Aquat. Sci*., 38: 1838-1855.

Jaiswar, A. K., P. K. Parida, S. K. Chakraborty and R. Palaniswamy. 2004. Morphometry and length-weight relationship of obtuse barracuda *Sphyraena obtusata* (Cuvier) (Teleostomi; Actinopterygii :Sphyraenidae) from Bombay waters, west coast of India. *Indian J. Mar. Sci.,* 33: 307-309.

Kasim, H. M. and T. S. Balasubramanian. 1990. Fishery, growth, yield per recruit and stock assessment of *Sphyraena obtusata* (Cuvier) off Tuticorin, Gulf of Mannar. *Indian J. Fish*., 37(4): 281-288.

King, M. 2007. *Fisheries biology assessment and management.* (2nd Ed.), Blackwell Scientific publications, Oxford, 381pp.

Mamuris, Z., A. P. Apostolidis, P. Panagiotaki, A. J. Theodorou and C. Triantaphyllidis. 1998. Morphological variation between red mullet populations in Greece. *J. Fish Biol*., 52: 107-117.

McHugh, J. I. 1954. Geographical variation in Pacific herring. *Copeia*, 2:139-151.

Melvin, G. D., M. J. Dadswell and J. A McKenzie. 1992. Usefulness of meristic and morphometric characters in discriminating populations of American shad (*Alosa sapidissima*) (Osteichthyes: Clupeidae) inhabiting a marine environment. *Can. J. Fish. Aquat. Sci*., 49: 266-280.

Modesto, T. and A. V. M. Canario. 2003. Morphometric changes and sex steroid levels during the annual reproductive cycle of the Lusitanian toad fish, *Halobatrachus didactylus. Gen. Comp. Endocr.*, 131: 220-231.

Muchlisin, Z. A., B. Zulkarnaini, S. Purnawan, A. Muhadjier, N. Fadli and S. H. Cheng. 2014. Morphometric variations of three species of harvested cephalopods found in Northern sea of Aceh Province, Indonesia. *Biodiversitas*, 15:142-146.

Mustafa, M. G. and A. C. Brooks. 2008. Status of fisheries resource and management approach in the open Beels of Bangladesh: a comparative case study. *Asian Fish. Sci.*, 21:189-203.

Okera, W. 1982. *Observations on the maturation condition of some pelagic fishes from northern Australian waters.* CSIRO Marine Laboratories, Report No. 144: 15 pp.

Pauly, D. 1984. *Fish population dynamics in tropical waters: A manual for use with programmable calculators.* ICLARM Studies and Reviews, 8: 325 pp.

Prasad, R. S., B. Santhosh, K. M. Abraham, S. Jasmine, S. Surya, K. N. Saleela and V. P. Benziger, 2021. Length-weight, length-length relationships and condition factor of obtuse barracuda *Sphyraena obtusata* Cuvier, 1829 (Pisces: Perciformes) from Vizhinjam coast, Kerala, India. *Indian J. Fish*., 68(1): 102-108.

Premalatha, P. and P. P. Manojkumar. 1990. Some biological aspects of two species of barracudas from the south west coast of India. *Indian J. Fish*., 37(4): 289-295.

R Core Team, 2020. R Core Team (2020). *R: A language and environment for statistical computing.* https://www.R-project.org/.

Sisneros, J. A., P. W. Alderks, K. Leon and B. Sniffen. 2009. Morphometric changes associated with the reproductive cycle and behavior of the intertidal-nesting, male plain fin midshipman *Porichthysnotatus. J. Fish. Biol.*, 74: 18-36.

Sivashanthini, K., G. Gayathri and K. Gajapathy. 2009. Length-Weight Relationship of *Sphyraena obtusata* Cuvier, 1829 (Pisces: Perciformes) from the Jaffna Lagoon, Sri Lanka. *J. Fish. Aquat. Sci.,* 4:111-116.

Somvanshi, V. S. 1989. Stock assessment of barracuda (*Sphyraena obtusata*) in the Gulf of Mannar off India. In: *Contributions to Tropical Fish Stock Assessment in India*. FAO/DANIDA/ICAR National follow-up training course on fish stock assessment. Cochin, India, 2-28 November, 1987: 87-101.

Surre, C., H. Persat and J. M. Gaillard. 1986. A biometric study of three populations of the European grayling, *Thymallusthy mallus* from the French Jura Mountains. *Can. J. Zool*., 64: 2430-2438.

Swain, D. P., B. E. Ridell and C. B Murray. 1991. Morphological differences between hatchery and wild populations of Coho salmon (*Oncorhynchus kisutch*): environmental versus genetic origin. *Can. J. Fish. Aquat. Sci*., 48:1783-1791.

Trapani, J. 2003. Morphological variability in the Cuatro Cienegas cichlid, *Cichlasoma minckleyi. J. Fish Biol*., 62: 276-298.

Vladykov, V. D. 1934. Environmental and taxonomic characters of fishes. *Trans. R. Can. Inst*., 20: 99-140.

Williams, F. 1959. The barracuda (genus *Sphyraena*) in British East African waters. *Ann. Mag. Nat. Hist*., 2: 92-128.

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*., 45:197-218.

Zar, J. H. 1996. *Bio-statistical Analysis*. Prentice-Hall, New Jersey, 662 pp.