



Morphometric and meristic analyses of horse mackerel, *Megalaspis cordyla* (Linnaeus, 1758) populations along the Indian coast

M. SAJINA, S. K. CHAKRABORTY, A. K. JAISWAR AND DEEPA SUDHEESAN

Central Institute of Fisheries Education, Fisheries University Road, 7-Bunglows, Andheri (W), Mumbai- 400 061
Maharashtra, India

e-mail : sajnaali2000@gmail.com

ABSTRACT

Populations of *Megalaspis cordyla* (horse mackerel) from four areas, two each from the east (Digha and Mandapam regions in the Bay of Bengal) and west (Cochin and Mumbai regions of the Arabian Sea) coasts of the Indian peninsula were studied based on conventional morphometry and meristics. Digital photographs of individual fishes were taken to extract 20 morphometric variables. Nine meristic characters were also counted. The analysis of variance of five morphometric traits showed significant difference between the fish samples of east and west coasts and those traits were eye diameter, prepelvic length, preanal length, anal fin length and caudal peduncle depth. The four traits that revealed location-wise variations were head length, preorbital length, second dorsal fin length and anal fin length. The chi-square test of meristic traits showed significant variation between the Bay of Bengal and Arabian Sea populations and also between the Mandapam and Digha populations. The morphometric and meristic study clearly revealed variations in morphometric traits of fishes from Arabian Sea and Bay of Bengal, which are definitely sufficient to separate these populations.

Keywords: Horse mackerel, Meristics, Morphometry, Phenotypic plasticity, Population variation

Introduction

Determination of population structure of exploited species is an essential component in successful management of fisheries. Specifically, this information can be used for applications ranging from the determination of appropriate conservation units to estimation of stock composition in mixed stock fisheries. Fish stocks are identified on the basis of differences in stock characteristics. Characters used to identify fish stocks can be purely genetic, purely environmental or those that may reflect both genetic and environmental variation (Swain *et al.*, 2005). Morphometrics and meristics are the two types of morphological characters that have been most frequently used to delineate stocks of a variety of exploited fish species (Murta, 2000; Silva, 2003; Turan, 2004).

Morphometrics is the empirical fusion of geometry with biology (Bookstein, 1997). Patterns of morphometric variation in fishes indicate differences in growth and maturation rates because body form is a product of ontogeny. Phenotypic plasticity of fish allows them to respond adaptively to environmental changes by modification in their physiology and behaviour which leads to changes in their morphology, reproduction or survival that mitigate the effects of environmental variation (Stearns 1983; Meyer, 1987).

Analyses of enumerable body features (meristics) have been widely used for studying stock structure of fishes. The most commonly enumerated features have been external, including number of fin spines and fin rays, gill rakers and scales. There is a long history of stock identification of fishes through meristic analysis; most fish species that occur as multiple stocks and that have been the subject of fishery management, also have received at least some meristic analysis (Waldman, 2005). Ecophenotypic variation of meristic expression has been clearly demonstrated in many species of fishes. There are instances in which ecophenotypic variation of meristic traits were more effective towards stock identification than are genetic approaches (Waldman, 2005). The morphometric and meristic characteristics are often analysed together for the purpose of population structure analysis.

The horse mackerel (*Megalaspis cordyla*, Family Carangidae), is a relatively large schooling carangid, which is among the group of high commercial interest in Indian pelagic fisheries. The morphometric and meristic studies so far published on *M. cordyla* is very limited; except for few studies such as Jaiswar and Acharya (1991) and Saker *et al.* (2004). The truss morphometric analysis of *M. cordyla* by Sajina *et al.* (2011) indicated significant phenotypic heterogeneity among populations in India. So far no work has been reported for stock structure

studies based on meristic analysis of Indian horse mackerel, *M. cordyla*. The present study aims to compare geographically distant populations of *M. cordyla* from the Bay of Bengal and Arabian Sea coasts of India based on conventional morphometry and meristics.

Material and methods

Sampling

The locations for horse mackerel sampling were selected following the regional grouping of maritime states of India as classified by Srinath (2003). The sampling locations in the east coast of India were Digha (State of West Bengal) and Mandapam (State of Tamil Nadu), representing the north-east and south-east zones, respectively. Similarly, Mumbai (State of Maharashtra) and Cochin (State of Kerala) were selected from the west coast, representing north-west and south-west zones (Fig. 1).

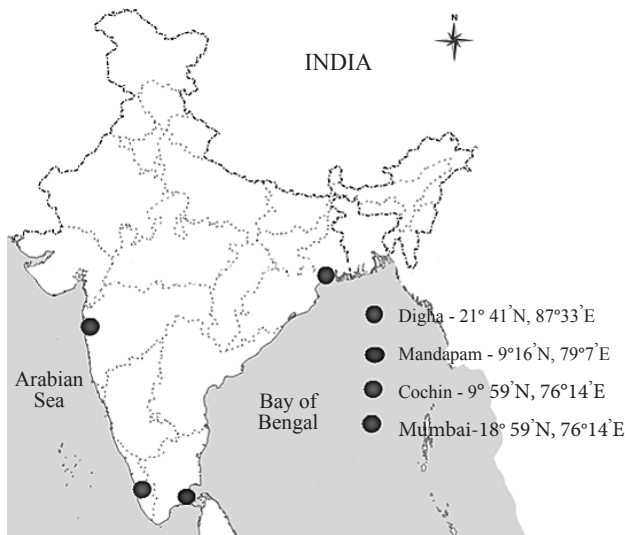


Fig. 1. Locations selected for sampling of horse mackerel

Measurement of morphometric distances

Digital images of individual fishes were taken to extract the morphometric variables. A total of twenty morphometric traits were considered in the present study (Fig. 2) and they were extracted from images using a combination of two softwares, tpsDig2 V 2.1 (Rohlf, 2006) and PAleontological STatistics (PAST) (Hammer *et al.*, 2001).

Acquisition of meristic data

A total of nine meristic characters were taken for the present study (Table 1). The meristic counts were done

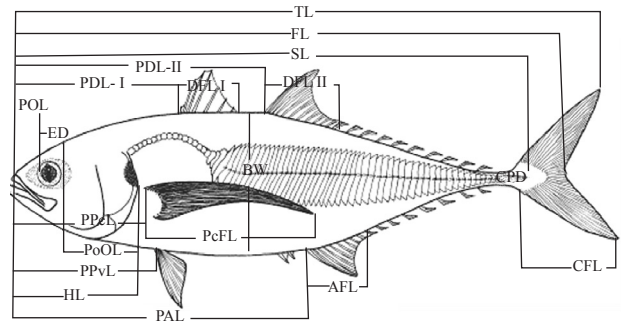


Fig. 2. Morphometric traits of *Megalaspis cordyla*

Table 1. Meristic characters of *Megalaspis cordyla* used for the present study

Acronym	Meristic character
DF1	Number of fin rays on first dorsal fin
DF2R	Number of fin rays on second dorsal fin
PcFR	Number of fin rays on left pectoral fin
PvFR	Number of soft rays on left pelvic fin
AFR	Number of soft rays on anal fin
DFNLT	Number of dorsal finlets
AFNLT	Number of anal finlets
GR	Number of gill rakers of first gill arch on left side of the body
SCT	Number of scutes on the straight part of lateral line on left side of the body

following the widely accepted criteria provided by Hubbs and Lagler (1958). The counts like number of gill rakers, scutes and rays on pectoral fin were taken from the left lateral aspect of the fish. The hard ray counts of all fins remained constant in all individuals and therefore they were not considered for the analysis.

Analysis of data

Data analyses were carried out separately for morphometric and meristic characters, since these variables are different both statistically (the former are continuous while the latter are discrete) and biologically (the latter are fixed early in development, while the former are more susceptible to the environment).

Morphometric data

PROC MEANS procedure (SAS Institute, 2000) was used to estimate the descriptive statistics *viz.*, minimum value, maximum value, mean, standard error and coefficient of variance, for the morphometric traits. The data were tested for normality of distribution and box plots were drawn by PROC UNIVARIATE and PROC PLOT procedures (SAS Institute, 2000). The significant source of

morphometric variation was detected by analysis of variance adopting the PROC GLM procedure of SAS as per Cody and Smith (1997). 'F' test was used to detect the significant differences between the variances of coasts, the locations within a coast and the sexes within a location. Wherever F test was found significant, differences between means were tested using paired difference procedure of SAS.

Meristic data

PROC MEANS procedure and PROC UNIVARIATE procedures were used to estimate the variability *viz.*, minimum value, maximum value, mode and standard deviation of the meristic traits. Mode may be preferred over the other two measures of central tendency when describing discrete categorical data and hence it is preferred in this situation where the greatest frequency of responses is important than scores at the centre. The significance in variation in meristic traits was detected by chi-square test adopting the PROC FREQ procedure of SAS as per Cody and Smith (1997). The meristic data were subjected to Principal Component Analysis (PCA) using PROC PRINCOMP procedure of SAS (Hatcher, 2003), which is a data reduction technique.

Results

The total length of *M. cordyla* for the overall samples ranged from 163.26 to 397.68 mm, with a coefficient of variation of 18.77% (Table 2). The maximum total length reported was a female specimen from Cochin, in the west coast. The maximum total length for east coast was 316.01 mm.

Table 2. Descriptive statistics of morphometric traits

Traits (mm)	Minimum	Overall (N= 371)		
		Maximum	Mean \pm SE	CV (%)
Total length	163.26	397.68	257.28 \pm 2.74	18.77
Standard length	139.23	347.33	222.67 \pm 2.46	19.48
Fork length	147.74	359.63	234.38 \pm 2.52	18.96
Head length	35.26	76.46	50.09 \pm 0.49	17.37
Pre-orbital length	6.95	20.91	10.59 \pm 0.10	16.64
Eye diameter	8.01	20.94	11.83 \pm 0.13	17.15
Post-orbital length	18.06	45.52	28.51 \pm 0.33	20.22
First pre-dorsal length	46.50	109.25	71.22 \pm 0.75	18.57
First dorsal fin length	17.41	48.74	29.34 \pm 0.32	19.43
Interdorsal length	1.83	12.35	4.26 \pm 0.07	29.25
Second pre-dorsal length	65.96	162.23	103.56 \pm 1.10	18.80
Second dorsal fin length	25.54	61.57	40.17 \pm 0.40	17.42
Pre-pectoral length	36.99	80.56	52.81 \pm 0.50	16.85
Pectoral fin length	41.10	137.18	74.37 \pm 1.11	26.27
Pre-pelvic length	41.96	95.63	62.36 \pm 0.63	17.85
Pre-anal fin length	78.41	188.84	121.53 \pm 1.33	19.34
Anal fin length	22.69	51.03	36.13 \pm 0.32	15.86
Maximum body depth	36.38	86.95	56.69 \pm 0.58	18.01
Caudal fin length	29.18	67.40	44.52 \pm 0.40	15.97
Caudal peduncle depth	3.71	8.18	5.70 \pm 0.05	14.25

The ANOVA of total length, standard length, body weight and maximum body depth showed significant difference between the two coasts and among the four locations, but none of them was found to have significant difference between sexes. After regression with standard length, five of the morphometric traits showed significant difference between coasts and the traits are the eye diameter, prepelvic length, preanal length, anal fin length and caudal peduncle depth. Between locations within the coasts, the F-test proved significance for five traits which included head length, preorbital length, second dorsal fin length, anal fin length and caudal peduncle depth. For all morphometric traits, F-test proved the hypotheses of no significant variation among the sexes.

The eye diameter in the east coast ranged from 8.11 to 15.04 mm with a mean of 11.00 mm, whereas the range and mean for west coast were 8.19-20.67 and 11.66 mm, respectively. The mean caudal peduncle depth of fishes from east coast was 6.56 mm whereas the same in east coast was 5.64 mm. The mean anal fin length of east coast

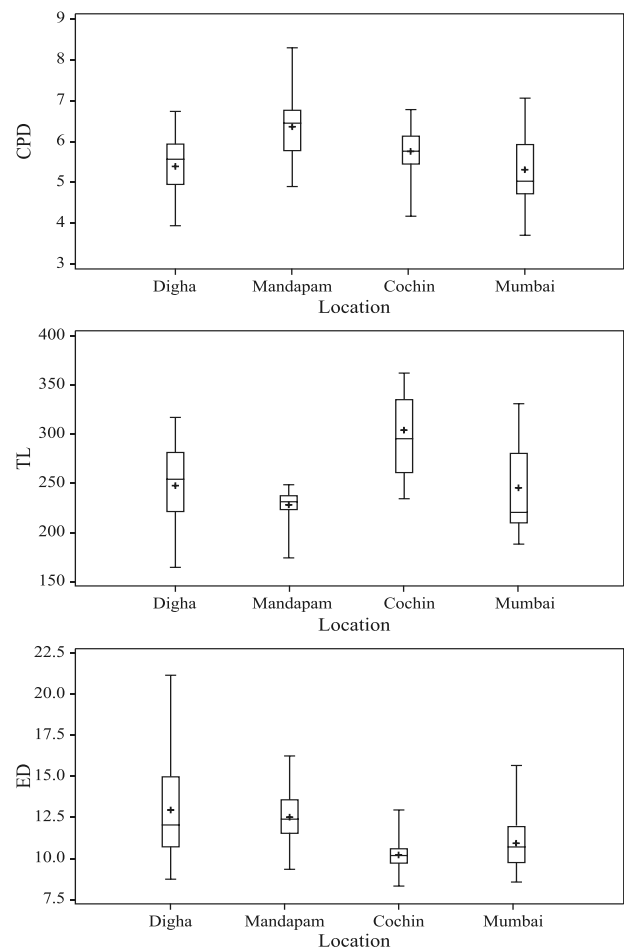


Fig. 3. Location-wise box plots of Total length (TL), Eye diameter (ED) and Caudal peduncle depth (CPD)

fishes was 34.97 mm whereas the same for west coast was 37.26 mm. The mean head length was lowest for Mandapam population and highest for Cochin population (Fig. 3).

The coast-wise, location-wise (within coast) and sex-wise (within coast) significance of variation of meristic traits along with their chi-square values are given in Table 3. Out of the seven counts analysed, five showed significant variation between east and west coasts of India.

Table 3. Test of significance of meristic traits

Meristic trait	Coast	Chi-square value			
		Location (Coast)		Sex (Coast)	
		East	West	East	West
Second dorsal fin rays	51.42**	56.73**	2.24NS	18.21NS	1.50NS
Pectoral fin rays	5.19NS	15.47NS	1.85NS	10.50NS	4.78NS
Anal fin rays	58.46**	28.61**	1.35NS	18.21NS	4.11NS
Dorsal finlets	23.40**	32.70**	2.57NS	9.58NS	3.04NS
Anal finlets	57.53**	17.75NS	2.53NS	14.43NS	6.11NS
Gill rakers on the first gill arch	33.03**	25.14**	4.51NS	5.85NS	4.95NS
Scutes on the straight part of lateral line	16.67NS	4.28NS	28.94**	29.55NS	19.20NS

** - Significant ($p \leq 0.001$); NS - Non significant

The traits that did not show coast-wise variation were pectoral fin rays and scutes on the straight part of lateral line. The analysis clearly shows that the two locations in the east coast viz., Digha and Mandapam, vary from those in west coast. Digha and Mandapam vary significantly in four traits and they were DFR2, AFR, DFINLT and GR. At the same time, Cochin and Mumbai samples showed significant variation in case of single meristic trait, SCT.

In the PCA analysis of the meristic traits of *M. cordyla*, the first three principal components (PCs) together explained 78.68% of total variation. PC1 contributed 43.97% of total variation, PC2 contributed

Table 4. Variable loadings in principal component analysis of meristic traits

Meristic trait	PC1	PC2	PC3
DFR2	-0.0375	-0.2982	0.4048
PcFR	-0.0133	0.1233	-0.0359
AFR	-0.0065	-0.2813	0.4303
DFINLET	0.0375	0.3244	-0.3722
AFINLET	0.0065	0.2553	-0.4065
GR	0.0733	0.7994	0.1880
SCT	0.9957	-0.0842	-0.0089

*Variable with meaningful loading as per Hatcher (2003) criteria

19.90% and PC3 accounted 14.81% for the same. Only single meristic trait showed significant loading on PC1 which was SCT. GR loaded significantly to the PC2, and DFR2 and AFR to the PC3 (Table 4, Fig. 4).

Discussion

The average length of fishes collected from west coast was significantly higher than east coast. Also, there were significant differences in body weight and maximum body depth of fishes, and west coast fishes were found to be heavier and deeper. Arabian Sea is one of the world’s most productive regions of the ocean and this is brought about through a range of physical processes like open ocean upwelling, wind-driven mixing, and lateral advection

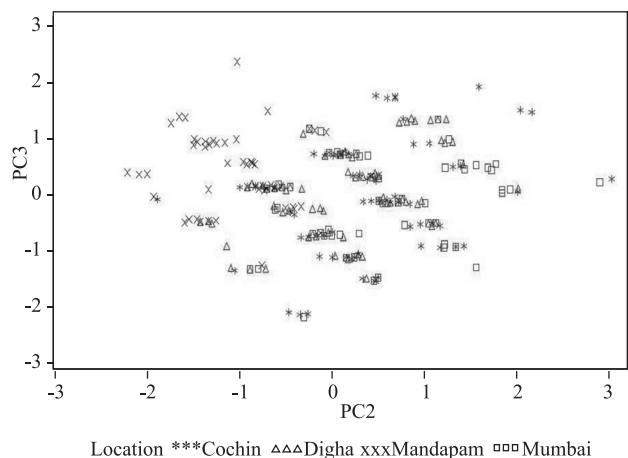
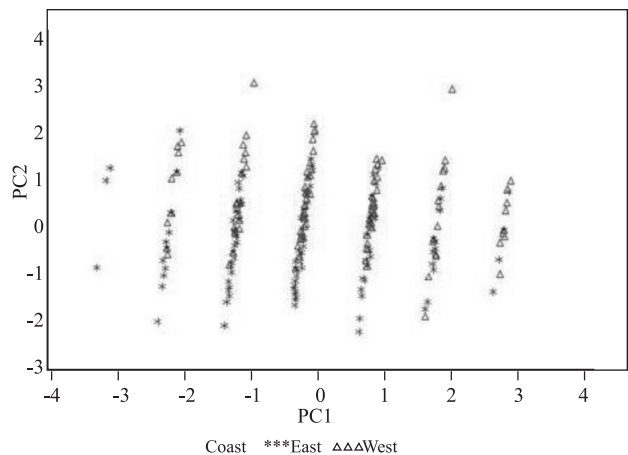


Fig. 4. Bivariate plot of scores of the two components (PC1 and PC2) extracted from meristics of *M. cordyla* by PCA

(Kumar *et al.*, 2009). In contrast, the Bay of Bengal is traditionally considered to be a region of lesser biological productivity, and recent measurements using clean techniques for phytoplankton C¹⁴ uptake also corroborate this fact (Kumar *et al.*, 2002). The productive Arabian Sea provides environment favourable for continuous supply of food for fishes such as horse mackerel and it may, in turn, explain why horse mackerel of these waters characterised by high growth parameters. Reuben *et al.* (1992) also reported differential growth parameters for *M. cordyla* along both east and west coasts of India.

The variation in eye diameter can be attributed to the developmental changes in fishes in their early stages corresponding to the light intensity in their habitat and it may reflect differences in turbidity of the habitat (Matthews, 1988). Masuda and Tsokamoto (1996) studied morphological development in relation to phototaxis and rheotaxis in the striped jack *Pseudocaranx dentex* and development of pigment in the retina and rod formation corresponding to the light intensity. Higgs and Fuiman (1996) analysed the relation between eye diameter and light intensity threshold for schooling in several species and found that there is a strong correlation between these parameters. Miyazaki *et al.* (2000) confirmed the same in *Pseudocaranx dentex*, another carangid fish. The recent study by Kumar *et al.* (2010) indicates reduced penetration of solar radiation in Bay of Bengal due to the large quantities of sediment influx. Hence the variation in eye diameter in fishes from east and west coasts of India can perhaps be attributed to the variation in light penetration and resultant light intensity in both seas and associated adaptive development in the species.

The study by Imre *et al.* (2002) demonstrated morphological variation in caudal area in brook charr from microhabitats differing in water velocity and they observed deeper caudal peduncle in fishes from turbulent waters. The water turbulence in Bay of Bengal is considerably higher than Arabian Sea. Hence, the variation in caudal peduncle depth in *M. cordyla* from Arabian Sea and Bay of Bengal could be a consequence of phenotypic plasticity in response to hydrological conditions.

The variations in second dorsal fin length and anal fin length between locations could be due to the variation in number of dorsal and anal finlets, respectively, between locations. The second dorsal fin length tends to be smaller for fishes with high number of dorsal finlets and the same in case of anal fin length and anal finlets. The least square mean of anal fin length and second dorsal fin length were significantly higher for the Mandapam population, which may be explained by the structured community

adaptations in the fishes inhabiting the coral reefs of Gulf of Mannar. The study by Korsmeyer *et al.* (2002) on swimming pattern of some coral reef fishes indicated the use of the soft dorsal and anal fins in swimming patterns using median and paired fins. The anal fin serves to stabilise the fish while it is swimming. The shorter anal fin in the eastern population may account for the turbulence in Bay of Bengal and associated adaptation. Morphometric differentiation between the samples in the head characters may reflect differential habitat use and variation in relative head length may be related to prey size (Gatz, 1979).

Fishes exhibit large scale plasticity in overall body shape and habitat associated morphological divergence is widespread in fishes, including intraspecific differences. It may be suggested that physical characteristics of living habitat can determine evolutionary and ecological conditions driving changes in the morphological characteristics of resident fish populations. Polymorphisms involve diversification of behavioural, morphological or life history traits in populations (Smith and Skulason, 1996). Such polymorphisms are more common in vertebrate populations than originally thought (Robinson and Wilson, 1994; Wimberger, 1994; Skulason and Smith, 1995). Phenotypic plasticity is the ability of a genotype to respond to alternative environmental conditions to produce an array of phenotypes (Thompson, 1991). The morphometric study of *M. cordyla* clearly depicted the variation of fishes from Arabian Sea and Bay of Bengal, though in small magnitude, but definitely enough to be considered as subpopulations which can be considered as separate management units.

The number of pelvic fin rays remained six in all samples, *i.e.*, one spine and five branched rays, similar to that in Mediterranean horse mackerel, *Trachurus mediterraneus* and bluefish, *Pomatomus saltatrix*, reported by Turan (2004) and Turan *et al.* (2006), respectively. The spinous first dorsal fin count also did not vary from eight, unlike the 7-9 range in Mediterranean horse mackerel (Turan, 2004). The single spinous rays associated with fins, like second dorsal fin, pectoral fin, pelvic fin and anal fin also remained constant in all individuals irrespective of coasts, locations and sexes. It indicates the lack of plasticity in the spinous rays of fins in *M. cordyla*.

The chi-square test showed significant variation between the Bay of Bengal and Arabian Sea populations and also between the Mandapam and Digha populations. It was again depicted by the bivariate plots of PC2 and PC3 components in Principal Component Analysis. Digha and Mandapam populations differed in DFR2, AFR, DFINLT and GR in chi-square test. Similarly, it was GR which

loaded in PC2 and DFR2 as well as AFR, which loaded in PC3, explained the separation of Mandapam in PCA.

The body scutes that loaded on PC1 did not bring any separation based on coasts or a location, suggesting the variation of number of scutes, is the character of all populations studied. FAO/SIDP (2000) has given a range of 51-59 scutes in the straight part of lateral line, whereas the same in present study was found to range from 52 to 62. The PCA of meristic traits clearly depicted the separation of Mandapam population through the bivariate plots of PCs. The meristic traits responsible for differentiation of Mandapam population were the counts of gill rakers, second dorsal fin rays and anal fin rays.

Variance in gill raker number within species was significantly greater in the tropical species (Moodie, 2004). The difference in number of gill rakers is related to the difference in inter-raker spacing (Amundsen *et al.*, 2004), variation of which between the two locations seems to be related to available prey size at each location (Matsumoto and Kohda, 2001). Physiochemical variables such as water temperature and salinity may affect gill raker morphology (Lindsey, 1981; Loy *et al.*, 1999). Hence, the variation in gill raker counts of horse mackerel samples, which showed a more clear separation of Mandapam population, could be caused by variation in ecological factors in their habitats. The lack of much variation between the meristic traits of Cochin and Mumbai samples shown by the chi-square test indicate the homogeneity of the two populations in the west coast of India. They differed in only the number of scutes, the trait which showed maximum within-sample variation and did not bring out differentiation of any samples.

The results obtained by the two methods, morphometric and the meristic analyses, were correlated and confirmative to each other. The variation of *M. cordyla* individuals from Arabian Sea and Bay of Bengal was clearly revealed by both methods. The traditional morphometry showed the variation of trait, caudal peduncle depth, between the coasts. The meristic analysis showed the significance of difference in the number of finlets between the two coasts, which are also related to the caudal region of fish. The Mandapam population exhibited a marked separation from all others for both morphometric and meristic characters indicating that there is a resident population of *M. cordyla* in the Gulf of Mannar fishing area. The relatively structured coral reef surrounding and environmental discreteness of the Gulf of Mannar, such as warm temperature, may lead to isolation of the population.

Not a single morphometric and meristic trait considered in the present study showed significant variation between the male and female individuals, proving the complete absence of sexual dimorphism in horse mackerel. In the study of Saker *et al.* (2004) also, there were no significant difference in the length-weight relationship of male and female *M. cordyla*.

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