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Delineation of the Stock Structure of White Sardine *Escualosa thoracata* (*Valenciennes,* 1847) Along the Indian Waters based on Biometric Analysis

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ABSTRACT

Background: An understanding of the stock structure of commercially exploited species is important for effective fisheries management. The white sardine *Escualosa thoracata* (*Valenciennes*, 1847) forms a significant fishery along with both the costs of India. The decline in the resource landings during the last decade along the whole range of its distribution necessitated the recent deliberations to recognize the likely existence of stocks. In the present study, fish stocks are typically identified based on the differences in phenotypic characteristics between fish from discrete units to assess the stock structure of white sardine in the Indian waters using a biometric analysis.

Methods: Different four distinct locations, two each from the west coast (Mumbai and Cochin) and east coast (Kolkata and Chennai) along the Indian peninsula were surveyed based on the geographical situation during 2016. The collected samples of *Escualosa thoracata* were determined morpho-meristic based deliberationsand subsequently, the data analysis was carried out to recognize the likely existence of stocks.

Result: Biometric analysis used as one of the important complementary contributions to manage and control the management-related problems in the future. The results obtained by the morphometric and the meristic analyses, were correlated and conformed.

Key words: Escualosa thoracata, Morpho-meristic, Phenotypic plasticity, Stock structure.

INTRODUCTION

Apart from major clupeoid fishes, the lesser sardines, a multispecies group, also happens to be a valuable fishery resource of India's coasts. The fisheries of *Escualosa thoracata* are almost neglected in the earlier years due to the availability of oil sardine in abundance (Nair, 1951). It supports economically important fishery along India's south-west coast, but it also occurs in swarms on the east coast. It assumed importance in recent years due to the demand of this species in domestic consumers. Ontogenic changes in body shape, particularly during a key life-history stages, typically resulted in morphometric characteristics (Dwivedi, 2013). Morphometrics and meristic characters have been most frequently used to delineate stocks of various exploited fish species (Murta, 2000; Silva, 2003). Patterns of morphometric variation in fishes showed distractions in growth rates because body form is a product of ontogeny. The phenotypic plasticity of fish allows them to respond adaptively to the dynamic nature of environmental changes by modifying their physiological and behavioral changes, which leads to changes in their morphology that mitigate the effects of environmental changes (Stearns 1983; Meyer, 1987). Morpho-meristic variation between different fish stocks can provide us a useful information which provides basis for its structure and can be applicable for studying short term, environmentally induced variation (Beg *et al.*, 1999). An analysis of morphological variations between different populations continues to have an important role to play in stock differentiation. Ihseen *et al.* (1981) found that morphometric and meristic characters in fishes provided useful knowledge for identifying marine fish stocks and spatial distributions.

Thus, the present study is aimed to delineate the stock of geographically distant population of *E. thoracata* in Indian waters to improve fisheries data outcomes for real-time management decision-making.

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MATERIALS AND METHODS

Study area

Total 334 specimens of *Escualosa thoracata* were collected in year 2016 in both the west coast (Cochin in Kerala and Mumbai in Maharashtra) and east coast (Kolkata in West Bengal and Chennai in Tamil Nadu). Collected samples were brought to the laboratory of Central Institute of Fisheries Education, Mumbai and washed thoroughlyand subjected to morphometric and meristic studies. Took 18 morphometric and 7 meristic traits with the help of vernier calliper in laboratory for further analysis.

Morphometric studies

Morphometric characters were measured by using scale and vernier calliper for accuracy to the nearest millimetre. Enumerated about 18 Morphometric traits for the present study. The description of the parameters is provided in Table 1.

Meristic studies

A total of 135 specimens of *E. thoracata* from each west coast and east coast in the year 2016 were brought to the laboratory and following meristic counts were made. The characters were counted by using magnifying lens and needle to separate the rays. The number of dorsal fin rays (NDFR), number of pectoral-fin rays (NPFR), number of pelvic fin rays (NPEFR). The number of anal-fin rays (NAFR), Pre-pelvic scute (PREPES), Post-pelvic scute (POPES).

Data analysis was carried out separately for morphometric and meristic characters because these variables are different statistically; the morphometric are continuous, varied due to environmental changes, while meristic are discrete characters fixed in developmental phases. 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. The meristic data were subjected to principal component analysis (PCA) using PROC PRINCOMP procedure of SAS.

RESULTS AND DISCUSSION

The total length of *Escualosa thoracata* for all collected samples ranged from 7.0 to 11.5 cm with a coefficient of variance of 9.31%. The maximum total length 11.5 cm was recorded in male specimens from Mumbai in the west coast. Among the representatives from the East coast, the maximum total length was reported from a specimen from Chennai (10.1 cm) (Table 2). The total length, standard length, body weightand maximum body depth showed a significant difference between the two coasts and the four locations but was not found in the sexes. After regression analysis with standard length, four morphometric traits such as the eye diameter, pre-pelvic length, preanal lengthand caudal depth indicated significant variance between west and east coasts. Between locations within the coasts, the F-test proved substantial difference for four traits such as head snout length, postorbital length, dorsal base length, body depthand caudal depth. For all traits, F-test depicted that there was no significant variation among sexes. The result indicated that a maximum co-efficient of variation is observed in snout length (13.55%) followed by postorbital length (12.59%), body depth (11.81%). The lowest coefficient of variation was recorded in fork length (8.15%). The eye diameter in the east coast ranged from 0.34 to 0.62 mm with a mean of 0.49 mm, whereas the range and mean in west coast from 0.39 to 0.70 and 0.52 mm respectively. The mean caudal depth of fishes from the west coast was 0.78 mm and 0.65 mm for the east coast. The mean head length

Table 1: Morphometric traits.

Parameters	Descriptions
Total length (TL)	The distance from the tip of the snout to the tip of the caudal fin.
Standard length (SL)	The distance from the tip of the snout to the base of.
Fork length (FL)	The distance between tip of snout to the end of middle caudal fin rays.
Pre-dorsal length (PDL)	Distance from the tip of the snout to the anterior margin of the base of the dorsal fin
Pre-anal length (PAL)	Distance from the tip of snout to the origin of anal fin.
Pre-PelvicLength (PPEL)	Distance from the tip of the snout to the origin of pelvic fin.
Pre-pectoral length (PPL)	Distance from the tip of the snout to the anterior margin of the base of the pectoral fin
Head length (HL)	The distance from the tip of the snout to the posterior margin of the operculum.
Body depth (BD)	Maximum vertical length of body (deepest part of the body).
Caudal depth (CD)	The minimum distance between dorsal and ventral profiles of the caudal peduncle region
Snout length (SNL)	The distance from the tip of the snout to the anterior margin of the orbit.
Inter orbital length(IOL)	Distance between the dorsal margins of two orbits of eyes.
Post-orbital length (POL)	The distance between posterior end of eye to the end of operculum.
Eye diameter (ED)	The distance from the anterior margin to the posterior margin of the eye.
Length between anal and pelvic (LBAPEL)	The distance between the posterior end of pelvic fin and origin of anal fin.
Depth at anal opening (DEPAOP)	Depth of the body at the origin of anal fin base.
Anal fin base length (ABL)	The distance between origin and end of the anal fin.
Dorsal fin base length (DBL)	The distance between origin and end of the dorsal fin.

was lowest for the east coast and highest for the west coast. Comparative variability among locations of total length, caudal depth, snout lengthand eye diameter of *Escualosa thoracata* is shown in Fig 1, 2, 3 and 4. Descriptive statistics of meristic traits is given in Table 3. Out of six characters, five showed the significant variations between east coast and the west coast. The traits which did not show coast-wise and location-wise variation was the number of pelvic fin rays. Five traits, *i.e*., NDFR, NPFR, NAFR, PREPES and POPES, show significant variation in the east and west coast. In the PCA analysis of the meristic traits of *E. thoracata*, 68.45% of total variations were explained by the first three principal components together. 34.68% of total variations contributed by PC 1, 21.45% by PC 2 and 15.33% contributed by PC3. Only one trait showed significant loading on PC1, which was POPES and NAFR loaded significantly to the PC2 and NDFR and NAFR loaded significantly on PC3 (Table 4).

The analysis clearly shows that the white sardine stocks from two locations on the east coast, *i.e*. Kolkata and Chennai, vary from those on the west coast. Apart from that, the stocks from Kolkata and Chennai significantly differed in two traits such as NDFRand NAFR. On the west coast, Kochi and Mumbai stocks also showed significant variation in three features such as NPFR, PREPES and POPES. While NPeFR did not show significant variation coast-wise, location wise and sex-wise also. Morphometric analysis revealed significant heterogeneity among the *E. thoracata*, which is used to separate stock on the Indian coast. The average length of white sardine samples collected from the west coast was significantly higher than the east coast. Also, there was a significant difference in body weight and maximum body depth of fishesand fishes from the west coast were found to be heavier and deeper. The Arabian Sea is one of the world's most productive areas of the ocean due to a wide range of geo-climatic phenomenon like upwelling, mixing of waterand lateral advection (Kumar *et al*., 2009).

In contrast, it is traditionally considered a region of lesser biological productivity in the Bay of Bengaland recent measurements for phytoplankton C^^{14} uptake also support this fact (Kumar *et al*., 2002). The productive Arabian Sea provides favourable conditions for the continuous supply of food for fishes such as white sardine. This might be the possible reason for this fish characterized by high growth parameters. The stock characteristics of *E. thoracata* were studied from the north-west coast of India (Raje, 1994, Prajapat, 2015, Rahangdale *et al*., 2016), south-west coast of India (Abdusamand *et al*. (2018) and central west coast of India (Gurjar *et al*., 2021).

Table 2: Descriptive statistics of various morphometric characters (N=334).

Variable	Min.	Max.	Mean	SE	CV (%)
TL	7.0	11.5	9.06	0.05	9.31
FL	6.2	10.2	7.75	0.04	8.15
SL	5.4	9.7	7.21	0.04	8.43
PDL	2.39	4.45	3.42	0.02	9.32
PPL	1.23	2.19	1.66	0.01	9.16
PPeL	2.38	4.66	3.49	0.02	9.28
PAL	3.78	6.79	5.29	0.03	8.96
HL	1.18	2.18	1.64	0.01	9.32
BD	1.56	3.06	2.15	0.02	11.81
CD	0.45	1.05	0.78	0.01	9.52
SNL	0.29	0.68	0.52	0.02	13.55
IOL	0.30	0.57	0.42	0.01	8.97
POL	0.46	1.08	0.77	0.01	12.59
ED	0.34	0.62	0.49	0.02	9.07
LBAPEL	1.36	2.52	1.9	0.01	10.18
DEPAOP	1.01	2.05	1.48	0.01	11.67
ABL	0.75	1.56	1.18	0.01	8.76
DBL	0.54	1.21	0.91	0.01	10.17

Table 3: Descriptive statistics of meristic characters.

Variable	Median	Mode	Frequency of mode	Min	Max
NDFR	14	14	62	13	17
NPFR	11	11	69	9	13
NPeFR	7	7	150	7	7
NAFR	16	16	46	11	19
PREPES	16	16	43	12	19
POPES	10	10	99	10	12

Table 4: Variable loading in principal component analysis of meristic traits.

Meristic traits	PC1	PC2	PC3
NDFR	-0.0372	-0.2567	0.3926
NPFR	-0.0129	0.1455	-0.2890
NPeFR	-0.0056	-0.2813	-0.0346
NAFR	0.0566	0.2544	0.4125
PREPES	0.0733	-0.0791	-0.0078
POPES	0.9527	-0.0813	-0.0056

Masuda and Tsokamato (1996) found the development of pigment in the retina and rod formation corresponding to the light intensity and morphological evolution in respect to phototaxis and rheotaxis in the striped jack *Pseudocaranx dentex*. Higs and Fuiman (1996) found the relationship between light intensity and eye diameter for schooling in several species. They identified that there is a strong correlation between light intensity and eye diameter. Matthews (1988) studied and depicted that the variation in eye diameter can be analysed to the developmental changes

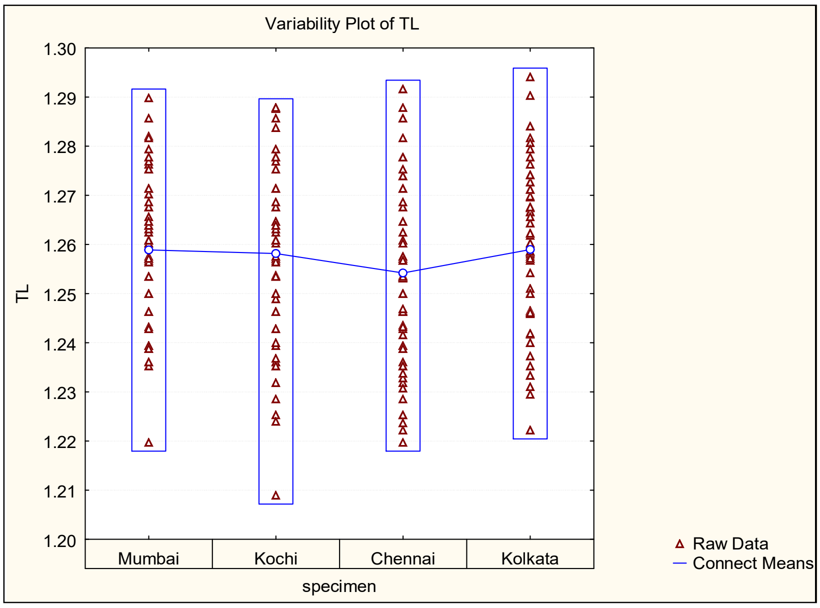

Fig 1: Variability plot of total length of *Escualosa thoracata.*

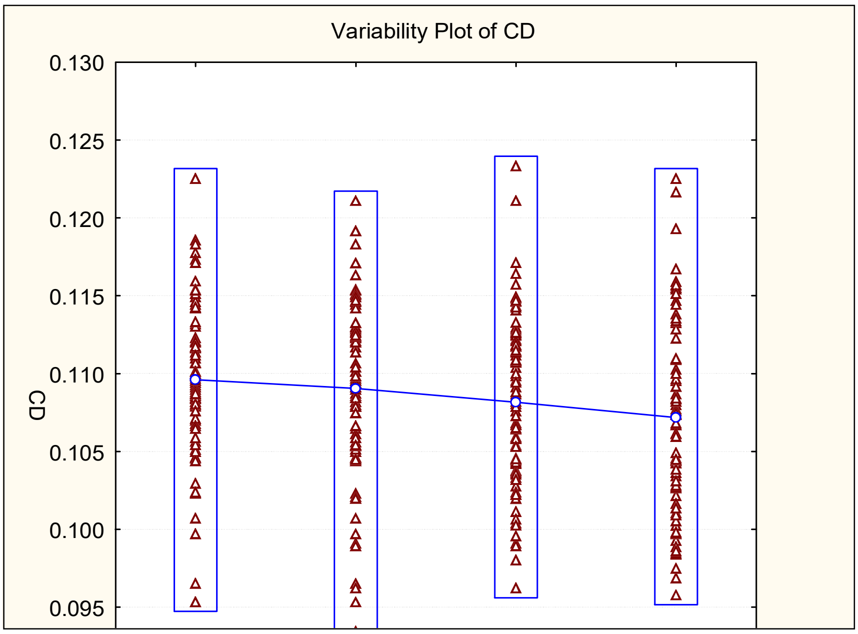

Fig 2: Variability plot Caudal depth of *Escualosa thoracata.*

in fishes in early stages corresponding to the light intensity in their habitat. It may reflect differences in turbidity of the habitat. Miyazaki *et al*. (2000) analyzed reduced penetration of solar radiation in the Bay of Bengal due to the large quantities of sediment influx. Hence, variation in light penetration and resultant light intensity in both seas is attributed to variation in eye diameter in fishes from India's east and west coasts and associated adaptive developmental changes in early stages in the species. Imre *et al*. (2002) demonstrated that microhabitats differing in water velocity showed morphological variation in the caudal area in brook charr observed deeper caudal peduncle in fishes from turbulent waters. The water turbulence in the Arabian Sea is considerably lower than the Bay of Bengal. the variation in caudal peduncle depth in *E. thoracata* indicates the possibility of a phenotypic plasticity in response to different hydrological conditions in the Arabian Sea and Bay of Bengal.

Plasticity in overall body shape and natural habitat associated with different morphological divergence is well known in fishes, including intraspecific differences. Hence, it was concluded that physical characteristics of living habitats can determine biological evolutionary and ecological driving changes in the morphological characteristics of habitual fish populations. Polymorphisms involve diversifying behavioral, morphological or life-history traits in populations

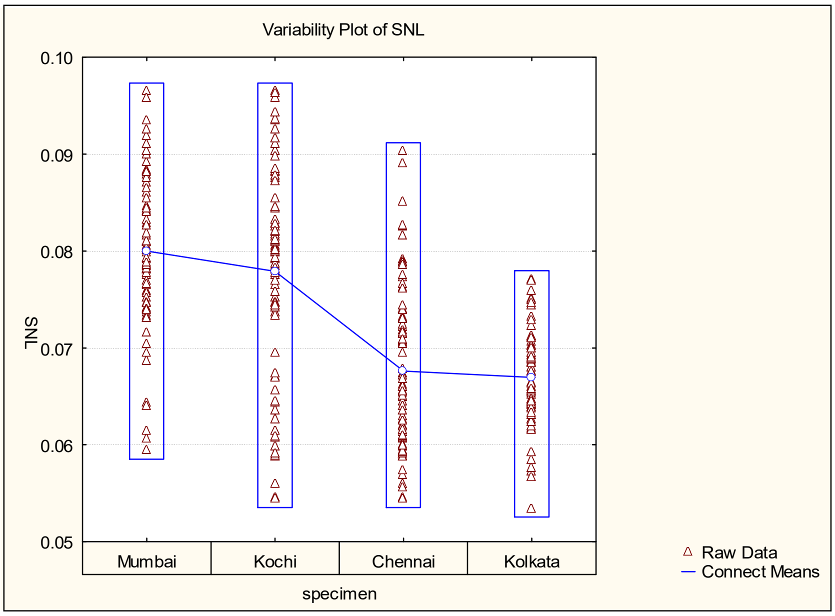

Fig 3: Variability plot of snout length of *Escualosa thoracata*.

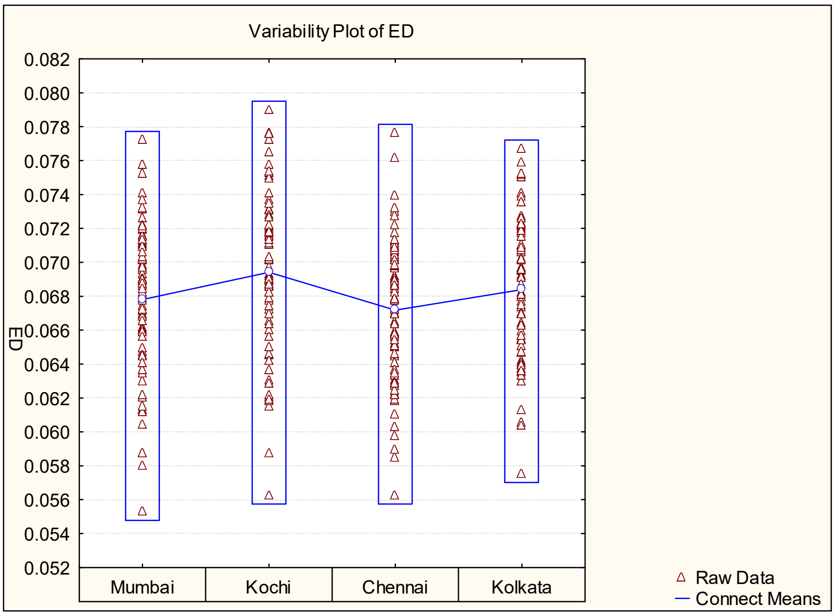

Fig 4: Variability Plot of eye diameter of *Escualosa thoracata*.

(Smith and Skulason, 1996). Such polymorphisms are more common in vertebrate populations than initially thought (Robinson and Wilson, 1994; Wimberger,1994; Skulason and Smith,1995). Thompson (1991) analyzed that phenotypic plasticity is the genotype ability to respond to alternative environmental conditions to produce a difference in phenotypes. The study of morphometric parameters of *E. thoaracata* clearly showed the variation of fishes from Arabian Sea and Bay of Bengal, though in a small magnitude, but surely enough to be considered as subpopulations which suggests the need for different type of strategies to manage the resources. Morphometric analyses have been used as a robust tool for discriminating biological groups (De La Cruz-Agüero *et al*., 2004). The Principal component analysis (PCA) showed significant variation between the Bay of Bengal and Arabian sea populations. The PCA of meristic traits depicted the separation of Mumbai population. The meristic characteristics were responsible for the differentiation of the Mumbai population. The results obtained by the two methods, morphometric and the meristic analyses, were correlated and conformed.

Conclusion

This biometric analysis of *E. thoracata from* the Indian coast showed a significant difference between the stock of the west coast and east coast. This studies can be beneficial and could be extended further on delineating the populations from all the geographical locations along the Indian coast.

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