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Stock structure analysis of Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) from south-east and south-west coasts of India using truss network system

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ABSTRACT

A total of 200 specimens of Indian mackerel (*Rastrelliger kanagurta*) were collected from Kochi in the south-west coast and Chennai in the south-east coast and they were subjected to truss analysis. A truss network was constructed by interconnecting 10 landmarks to form a total of 21 truss distance variables extracted from the landmarks. The transformed truss measurements were subjected to factor analysis which revealed that there is no separation of the stocks along south-east and south-west coasts. Thus the present study has indicated that the population of Indian mackerel from south-east and south-west coasts remains the same.

Keywords: Indian mackerel, *Rastrelliger kanagurta,* Stock structure, Truss network

Introduction

The Indian mackerel, *Rastrelliger kanagurta* forms one of the major single species fisheries contributing >5% to the landings along the Indian coasts (CMFRI, 2013). Knowledge on the stock structure of the target species is fundamental to formulate resource management platform and sustaining the marine fish stocks (Shaklee and Bentzen, 1998). However, since the last 10 years, mackerel landing has increased along the south-east coast which is assumed to be the after effect of changing climatic conditions (Vivekanandan, 2011). Therefore there is an urgent need to assess the changes in the stock structure of the species along the south-east and south-west coasts of India.

Attempts were made in the past to identify the stock structure of Indian mackerel from the east and west coasts based on the traditional morphometry (Seshappa, 1985). Truss network system (Strauss and Bookstein, 1982) is a quantitative method for describing the shape of fish (Cavalcanti *et al.,* 1999; Sen *et al.,* 2011) as well as for studying the morphometric variations between species and also between stocks of a species (Turan, 1999). Truss network system (Strauss and Bookstein 1982; Bookstein *et al.,* 1985) is more effective in identifying stocks and differentiating species in comparison with the traditional morphometric methods. An attempt was made by Jayasankar *et al.* (2004) to discriminate the phenotypic stocks of Indian mackerel.

In the present study, the stock structure of Indian mackerel from south-east and south-west coasts of India was carried out using the truss network system.

Materials and methods

Sample collection

A total of 200 specimens of Indian mackerel were collected from catches of ringseiners as well as trawlers at two locations *viz*., Chennai in the south-east coast and from Kochi in the south-west coast of India during February-November 2011 (Fig. 1). The collected fish specimens were placed in insulated box with ice packs and brought to the laboratory for further analysis.

Truss morphometrics

The specimens were placed on a water resistant paper and the body position and fins were teased into natural position to identify the landmarks. A total of twenty one truss distances were measured along the entire body surface on the left side of the fish *i.e*. head, trunk and tail using the paper and pin method (Strauss and Fuiman, 1985) (Fig. 2).

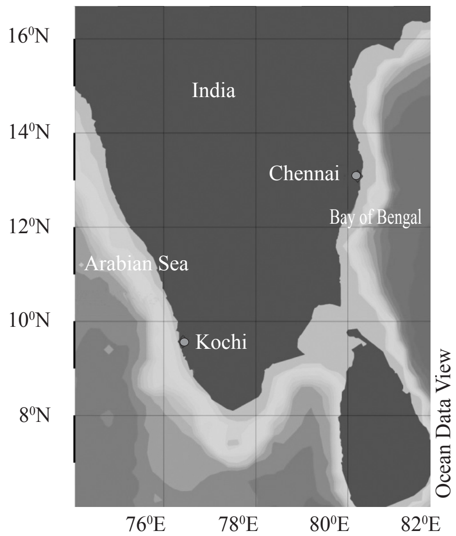

Fig. 1. Map showing sampling sites

These distances were based on morphologically significant anatomical locations or points called 'landmarks'. In the present study, a truss network of Indian mackerel was constructed based on 10 homologous anatomical landmarks (Table 1). At the point of the landmark, a hole was made on the water resistant paper, using a dissecting needle. The landmarks on the specimen were marked on the water resistant paper, using a dissecting needle. These points were then transferred to a graph sheet and the X-Y coordinate data were extracted. The X-Y co-ordinate data were used to calculate the truss distances between pairs of landmarks using the Pythagorean theorem, $D = \sqrt{(x1 - x2)2 + (y1 - y2)2}$ (Jayasankar *et al.,* 2004; Gopikrishna *et al.,* 2006).

Table 1. Landmarks used for extracting truss measurements from *R. kanagurta*

Landmark No.	Landmark position
1	Anterior tip of snout on upper jaw
2	Insertion of pre-opercle below posterior margin of eye
3	Nape above insertion of opercle
4	Origin of pelvic fin
5	Origin of first dorsal fin
6	Origin of first anal fin
7	Origin of second dorsal fin
8	Insertion of anal fin
9	Dorsal origin of caudal fin
10	Ventral origin of caudal fin

Transformation for removing size dependent effects

The size dependent variation in the whole data may discriminate the stocks (Humphries *et al.,* 1981). There were significant correlations observed between body size and the truss distances. Hence, the transformation of the absolute truss distances into size dependent shape variables

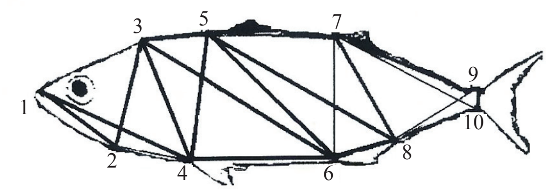

Fig. 2. Truss network of Indian mackerel showing the 21 variables extracted from 10 landmarks (Jayasankar *et al.,* 2004)

was carried out. First of all, outliers were removed based on Cook's distance estimates using PROC ROBUSTREG procedure of SAS (SAS Institute, 2010). A total of 120 measurements were selected after removing the outliers. Further, the size dependent effects were removed using an allometric approach by modifying the formula provided by Ihsen *et al.* (1981) and Hurlbut and Clay (1998). Data were transformed using the formula:

$M_{adj} = M\,(SL_{mean} / SL)^{ß}$

Where,

M_{adj} : Transformed morphometric measurement
M : Original morphometric measurement
SL : Standard length of fish
SL_{mean} : Overall mean standard length of the fish
ß : Within group slope of the linear regression between log transformed M and log transformed SL

Multivariate analysis

The Mardia's test was carried out to check the multivariate normality in the transformed truss distance data (Cox and Small, 1978). PROC MODEL procedure in SAS (SAS Institute, 2010) was used to carry out the Mardia's test for multivariate normal distribution. Further these truss measurements were subjected to Factor Analysis (FA) using the PROC FACTOR procedure of SAS (Hatcher, 2003) to find out whether the samples from south-east and south-west coasts belong to same stock or different stocks. A maximum likelihood method was used to extract the factors. The retained factors were subjected to rotation procedure by the varimax (orthogonal) rotation. For identifying the variables those demonstrate high loadings for a given component, rotated factors were subjected to scratching procedure described by Hatcher (2003).

Results and discussion

The factor analysis revealed that there is no significant morphometric variation between individuals obtained from south-east and south-west coasts and the variables with high loadings on the first three factors were not useful in distinguishing these samples. The results revealed that there is a single stock of Indian mackerel existing along the south-east and south-west coasts of India.

Differentiation of population between south-east and south-west coasts of India

The first three factors explained 92.5% of the total variation in the data; with first second and third factors contributing 70.93%, 16.24% and 5.33% of the variation respectively. The variables 3-6, 5-6, 5-7 and 5-8 had the highest loadings on the first factor. These factors were concentrated on the middle portion of the body. The variables 1-3, 6-7, 6-8, 7-8, 7-9 and 7-10 loaded on second factor were related to the anterior tip of snout on upper jaw, anal fin region, dorsal fin and caudal fin regions. The factor 3 was loaded heavily with truss variables 8-9 and 8-10 which were related to the caudal fin region. However, none of the factors have shown separation of the samples from south-east and south-west coast populations. Moreover, bivariate score plots between three factors revealed great degree of morphological homogeneity between Indian mackerel populations from Chennai and Kochi regions (Fig. 3).

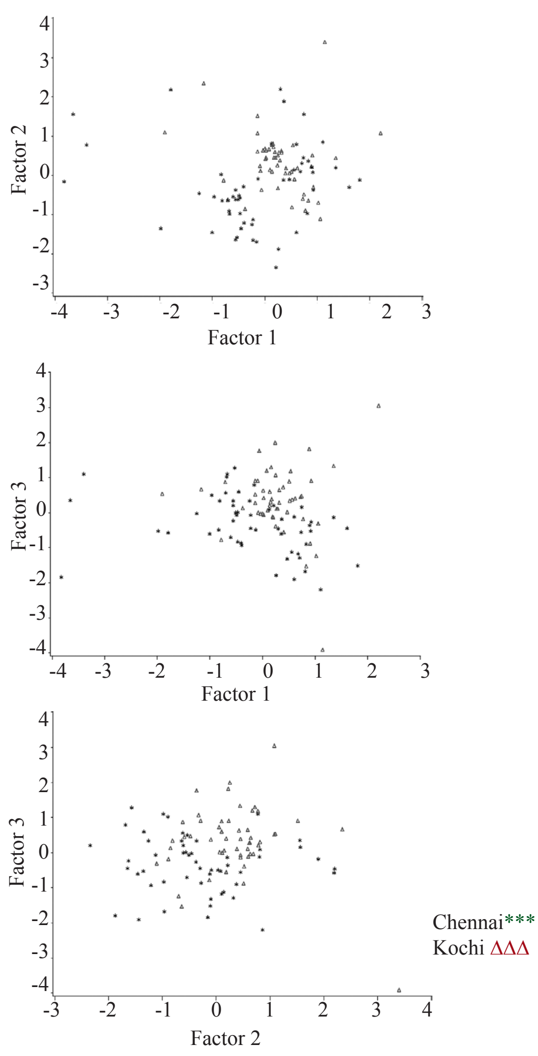

Fig. 3. Bivariate plots of scores on the first three factors extracted from 21 point truss measurements of *R. kanagurta* from south-east and south-west coasts of India

The truss morphometric analysis has revealed phenotypic homogeneity among the populations along the south-east and south-west coasts of India. The identification of distinct populations or stocks which are geographically or temporarily isolated from one another forms one of the important aspects regarding fisheries management (Booke, 1981). But, in the case of Indian mackerel, the migratory behaviour of the species gives more chance for intermixing of stocks and therefore no reproductive isolation or separation of spawning grounds is observed which are important factors regarding stock separation (Hoolihan *et al.,* 2006; Buckworth *et al.,* 2007; Shepard *et al.,* 2010; Sajina *et al.,* 2011; Kumar *et al.,* 2012)

The present analysis identified a single stock of Indian mackerel along south-east and south-west coasts of India, which demands the management of the species as a single unit. However, it is recommended that genotypic methods in addition to the present phenotypic study may also be carried out for the confirmation of the present results. The observations from the present study can be considered as a baseline for further research in future

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