

Stock Structure Analysis of Indian Mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) along the Indian Coast

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Abstract

The Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) forms a commercially important single species pelagic fishery in India, especially along the west coast. Therefore, information on the stock structure of this resource is of paramount importance for adopting proper management measures. A truss network was constructed by interconnecting 16 landmarks to form a total of 36 truss measurements, based on 337 samples collected from five populations representing off the Veraval and Mumbai coasts in northwest zone, Goa, Mangalore and Cochin in southwest zone. The common factor analysis (CFA) of truss network indicated body depth related traits loading heavily on first factor, shape related traits belonging to finlet area in the caudal portion on second factor and traits in middle portion of the body on third factor. The analysis revealed that, Indian mackerel exists as a single stock along the west coast of India, but the reduced intermixing of populations of distant locations has induced some morphological differentiation, which is progressive along the coast and in significant magnitude between very distant populations.

Introduction

Knowledge of stock structure of the target species is fundamental to scientific resource management as well as marine stock enhancement programs (Shaklee and Bentzen, 1998) and it is necessary to achieve sustainable yield, avoid recruitment failures, rebuild overfished stocks, as well as to conserve threatened and endangered species. However, despite its importance in the development and management of fishery, stock identification continues to be an afterthought, and hence there is a great need for stimulating new researches on stock identification of those stocks which are being assessed without reliable stock identification (Cadrin, 2005).

Among all the stock identification methods available, the analysis of morphometric characters is one of the most commonly used methods. Morphometric characterizations may be able to provide conceptual links between morphology and the genetic, developmental, and evolutionary processes and factors that influence it. The traditional morphometric methods are always associated with limitations in characterizing fish shape, which measure repeatedly along the length of the body

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axis and tend to cluster around the head (Creech, 1992). However, to overcome the inherent weaknesses of traditional morphometric methods, a system of morphometric measurements called the Truss Network System (Strauss and Bookstein, 1982) has been proposed and increasingly used for the purposes of stock identification and stock differentiation. It is more useful than the traditional morphometric methods to discriminate 'phenotypic stocks', groups of individuals with similar growth, mortality and reproductive rates (Booke, 1981). The developments of digital imaging systems, computer aided image analysis systems and advances in analytical methods revolutionized the field of morphometrics, and have increased the power of morphometric analysis for stock identification and stock delineation (Cadurin and Friedland, 1999).

There have been very few attempts to study the stock structure of Indian mackerel. The early attempts to study the stock structure of Indian mackerel from the east and west coasts of India were based on the traditional morphometry and meristics (Seshappa, 1985). Jayasankar et al. (2004) used truss protocol system and genetic analysis for studying the stock structure of Indian mackerel from three selected centers of east and west coasts of India. However, so far no comprehensive attempt has been made to study the stock structure along the entire length of west coast of India. The present study using truss morphometry can provide an insight on the stock structure of Indian mackerel as well as it will form a suitable platform for advanced stock identification techniques such as meristics, otolith elemental composition, fatty acid profile and molecular marker tools in future.

Materials and Methods

Sampling

The samples of Indian mackerel were collected from locations along the five maritime states: Veraval (Gujarat), Mumbai (Maharashtra), Colva (Goa), Mangalore (Karnataka) and Cochin (Kerala) (Fig. 1). These sampling locations were grouped into two zones following the regional classification of maritime states of India by Central Marine Fisheries Research Institute (Srinath, 2003), the northwest zone (Gujarat and Maharashtra states) and the southwest zone (Goa, Karnataka and Kerala states). In order to avoid the errors due to seasonal variation, fish samples from all the five locations were collected within one month. Morphological identification of the species, *Rastrelliger kanagurta* was done based on the description given by FAO species identification sheets (Fischer and Bianchi, 1984), and the specimens only with normal morphological features were used for the present study.

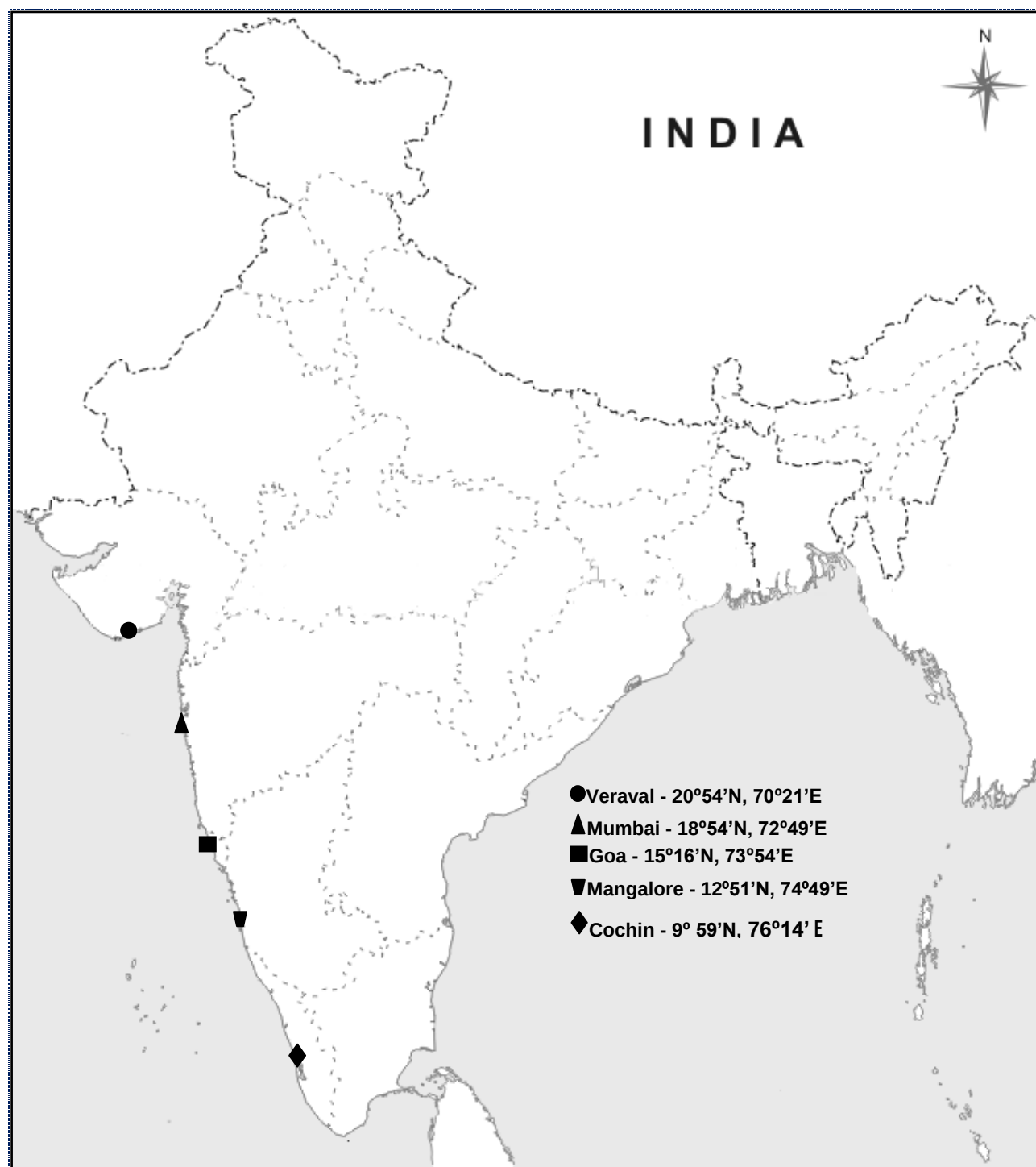


Fig.1. Locations selected for sampling of Indian mackerel.

Digitization of samples

Digitization of the image was done immediately after collecting the individuals from the sampling sites. In order to digitize the samples, they were first cleaned in running water, drained and placed on a flat platform with vertical and horizontal grids. The distances between the vertical as well as the horizontal grids were fixed in such a way that one square unit covers an area of one cm²

which was used for calibration at later stages of image processing and data acquisition. The fins were erected and placed on the platform so that the origin and insertion points are visible. Each individual was labeled with a specific code to identify it in the image. For digitizing images of individual fishes, a Sony Cybershot DSC series digital camera was mounted on a leveling tripod with a bubble level indicator to rectify the inclination if any. The inclination of the tripod and platform was leveled by the bubble level for perfect alignment.

Morphometric measurement

A linear combination of two softwares, tpsDig2 V 2.1 (Rohlf, 2006a) and PAleontologicalSTatistics (PAST) (Hammer et al. 2001) was used to extract morphometric data from the images of each specimen. All the images were first converted from JPEG (*.jpeg) to TPS (*.tps) format by using a utility program, tpsUtil V1.38 (Rohlf, 2006b). The data encrypted tps format image files from tpsDig were used as input source in the PAST and the data on distances between the co-ordinates were extracted.

The truss protocol of Indian mackerel in the present study was based on 16 landmarks (Table 1) and the truss network was constructed by interconnecting the landmarks to form a total of 36 truss measurements (Fig. 2).

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

Landmark Number	Landmark Position
01	Anterior tip of the snout on the upper jaw.
02	Posterior edge of supra occipital bone
03	Origin of first dorsal fin
04	Insertion point of the last dorsal fin ray of first dorsal fin
05	Origin of the second dorsal fin
06	Insertion point of the second dorsal fin.
07	Origin of the third dorsal finlet from anterior end.
08	Insertion point of last dorsal finlet.
09	Dorsal origin of the caudal fin
10	Ventral origin of the caudal fin
11	Insertion point of the last anal finlet.
12	Origin of the third anal finlet from anterior end
13	Insertion point of the anal fin.
14	Origin of the anal fin.
15	Origin of the pelvic fin.
16	Intersection of preopercle and operculum on the ventral side of the body

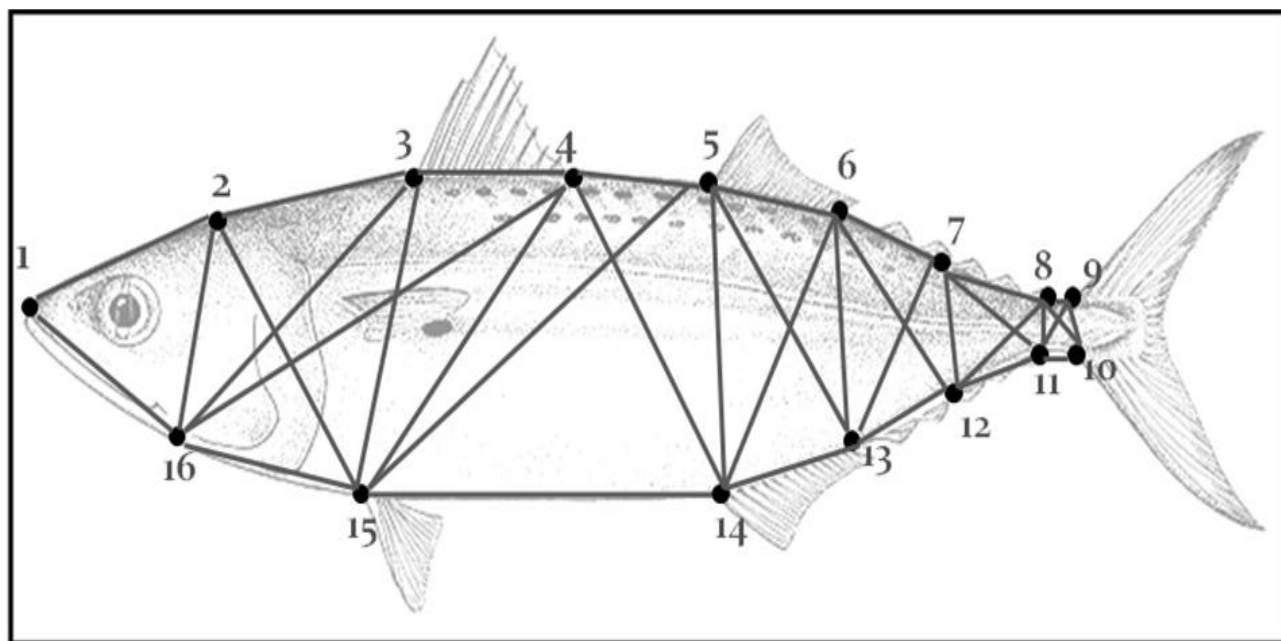


Fig. 2. The complete truss network of *R. kanagurta* showing the 36 truss variables.

Analysis of data

All the truss measurements were log transformed, tested for normality and the outliers were removed before further analysis. The analysis was carried out to differentiate the zones, populations and sex. Size dependent variation was removed from the log transformed data using the allometric approach (Reist, 1985).

The 36 truss measurements were subjected to FACTOR analysis using PROC FACTOR procedure of SAS (SAS Institute, 2000). Maximum likelihood method was used to extract the factors. Scree plot and cumulative variances explained by the factors were taken into consideration to retain the number of factors for rotation procedure. Only retained factors were subjected for rotation procedure by 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

The cumulative of first three factors explained 67.98 percent of the total variation and proportion of variance explained by each factor is depicted as scree plot (Fig. 3). As per Hatcher (2003) criteria, the variables 2-15, 2-16, 3-15, 3-16, 4-14, 5-13, 5-14, 5-15, 6-13, 6-14, 7-13, 8-11 and 9-10 were loaded on the first factor that explained 35.39 percent of the total variation. These 13 truss variables were related to depth of body across the entire length of fish. The truss variables 7-8, 7-11 and 7-12 were loading heavily on factor 2 that explained 20.04 percent of the total variation. These three variables found to cover the last three dorsal and finlet region. The factor 3 was loaded

heavily with truss variables 3-4, 4-15 and 4-16 and the three variables are related to the middle region of the body encompassing first dorsal, pelvic and posterior opercular area.

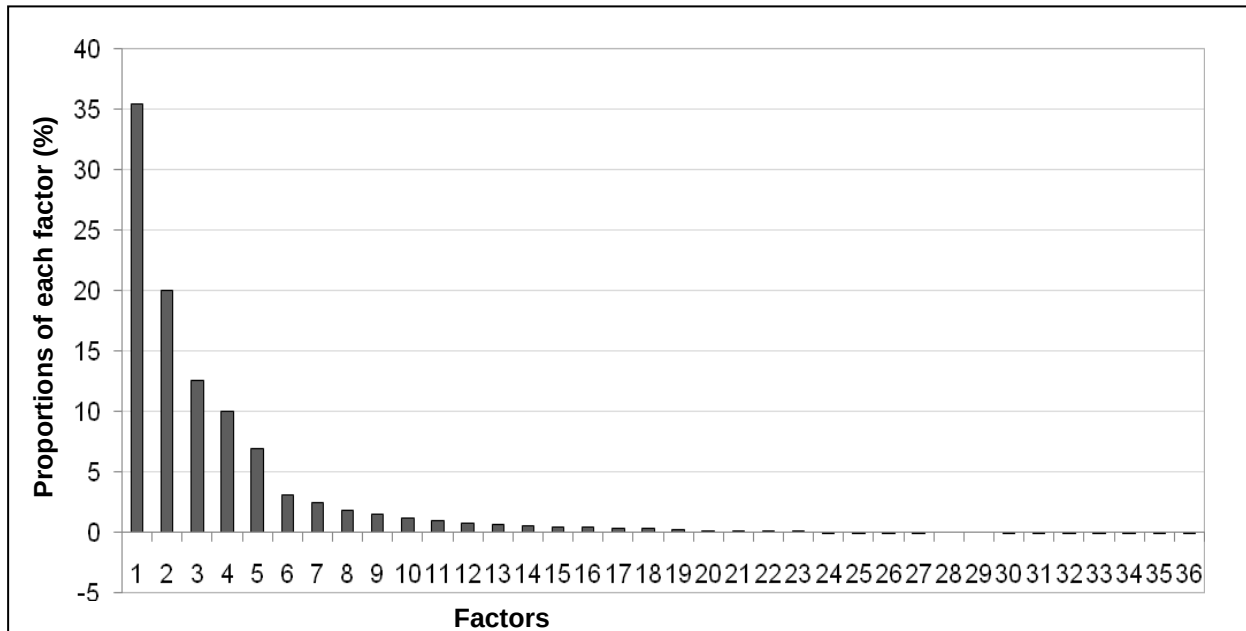


Fig. 3. Scree plot of eigenvalues for truss measurements.

The bivariate plots between three factors revealed slight separations of the populations of northwest and southwest zones (Fig. 4), even though the populations from five locations formed a single cluster (Fig. 5). The bivariate plots formed a single cluster for the sex, revealing no sexual dimorphism in the species.

When the factor analysis of the size corrected truss variables of Veraval and Cochin populations was performed separately, first three factors explained 73.99 percent of total variation. The factor 1 was heavily loaded by the body depth related variables, factor 2 was loaded with variables related to middle region of the body encompassing first dorsal, pelvic, posterior opercular and factor 3 loaded on variables related caudal region. The bivariate plot indicates slight separation of Veraval and Cochin populations (Fig. 6).

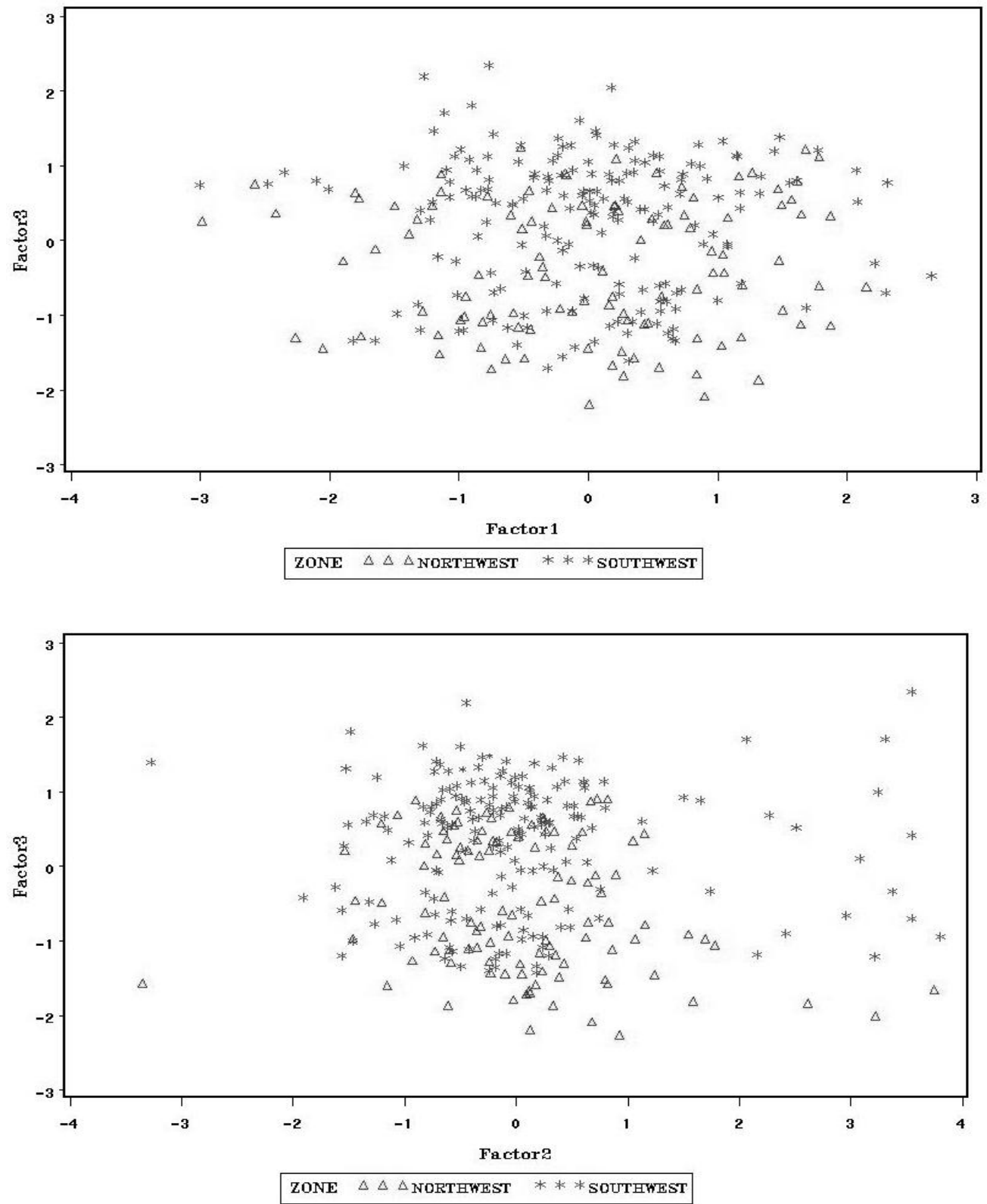


Fig. 4. Bivariate plots of scores on the first three factors extracted from 16 point truss measurements of northwest and southwest zone stocks of *R. kanagurta*.

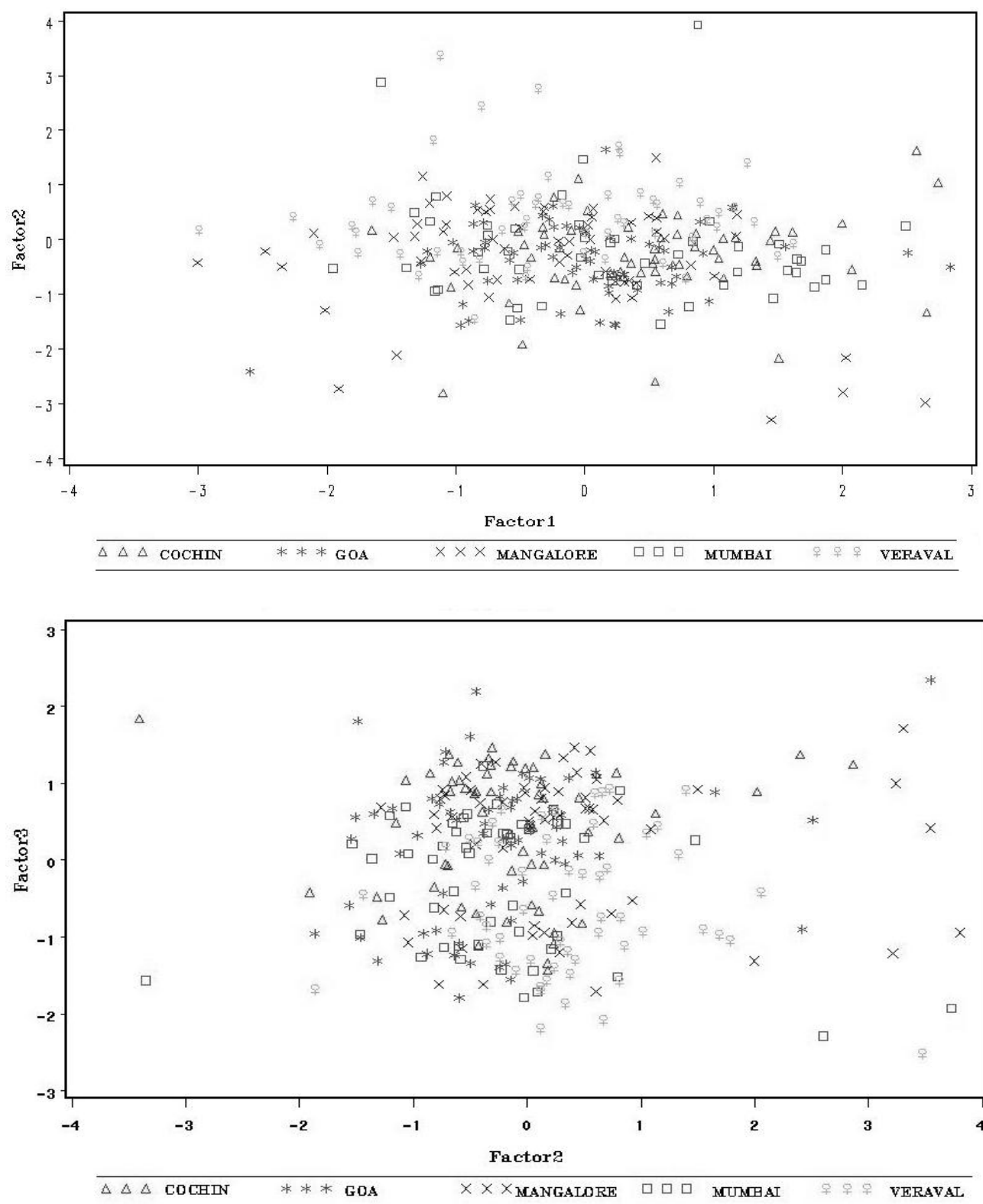


Fig. 5. Bivariate plots of scores on the first three factors extracted from 16 point truss measurements of five populations of *R. kanagurta*.

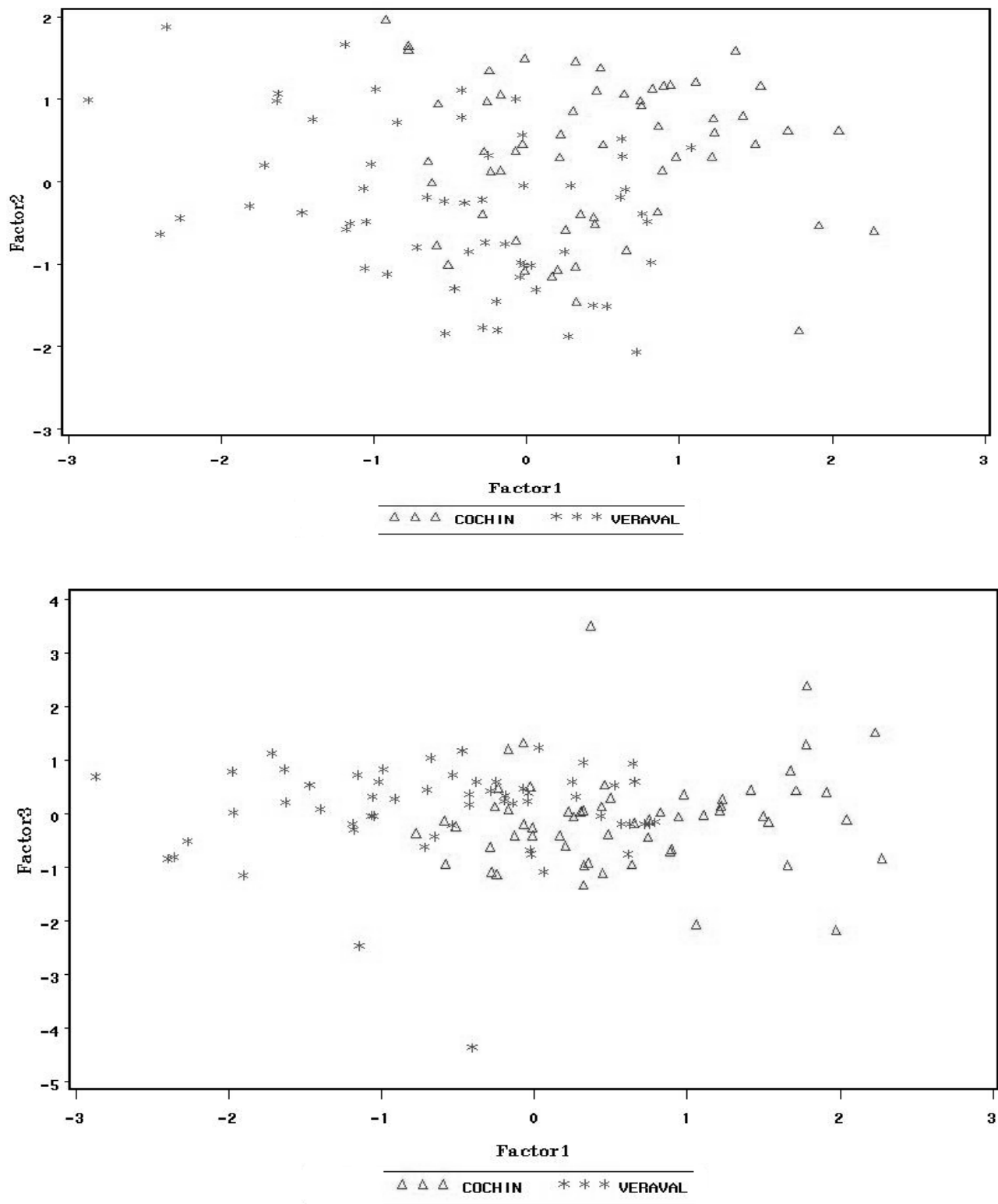


Fig. 6. Bivariate plot of scores on the two factors extracted from 16 point truss measurements of Veraval and Cochin stocks of *R. kanagurta*.

Discussion

The formations of biologically meaningful groupings on specific anatomical regions were the primary mode of observation. All landmark based morphometric methods face the fundamental challenge of removing variation in size from variation in shape (Parsons et al. 2003). In order to remove the size dependent variation from the truss variables, the method described by Reist (1985) was adopted for the present work. Tzeng (2004) had also used the same allometric method in spotted mackerel (*Scomber australasicus*) off Taiwan. Since standard length was taken as the index of size, the length related size effect might have been removed completely, leaving the depth related size effect which got loaded in the first factor. Cavalcanti et al. (1999) had also reported similar variable loading on first component while analyzing the morphometry of selected serranid species using principal component analysis (PCA).

The three variables loaded heavily on the second factor were found to cover the last three dorsal and finlet region. PCA of truss variables by Jayasankar et al. (2004) on Indian mackerel from south Indian coasts had also revealed that the area encompassing depth between the origins of second dorsal and anal fin, and caudal peduncle depth has high component loadings. This particular morphological variation herein observed can, however, be given a functional interpretation, being conceivably related to differences in habitat ecology of each population. The northern parts of Arabian Sea receive more river discharges and are more turbulent as compared to southern parts and hence the resultant difference in swimming pattern of the fishes might have accounted for the variation in morphology of the caudal region.

The three variables loaded on third factor are related to the middle region of the body encompassing first dorsal, pelvic and posterior opercular area. The truss network system poses no restriction on the directions of variation and localization of shape changes, and is much effective in capturing information about the shape of an organism (Cavalcanti et al. 1999). Truss boxes being with a uniform network over the entire region of the body, theoretically it should increase the likelihood of extracting morphometric differences between specimens (Turan, 1999).

The analysis of truss morphometry revealed the existence of a slight progressive variation among the populations of *R. kanagurta* along the west coast of India, which became prominent between the most distant Veraval and Cochin populations. It is a migratory species and many researchers had attempted to study the migration (Prabhu and Venkataraman, 1970), still the exact migration pattern is yet to be explored in full. The migratory behavior results in the intermixing of stocks and gives less chance for reproductive isolation and separation in the spawning grounds, which are important factors, concerning stock delineations.

Conclusion

It can be concluded that the Indian mackerel exists as a single stock along the west coast of India, and the reduced intermixing of populations of distant locations has induced some morphological differentiation, which is progressive along the coast and in significant magnitude between very distant locations i.e. Veraval and Cochin. Stock identification studies on mackerel can be explored with more multidisciplinary tools by taking account of the fishery in east coast of Indian peninsula. As far as the worldwide mackerel fishery is concerned which span over Exclusive Economic Zone of many countries, international collaborative efforts in research is suggested in order to manage and explore the fishery in full.

Acknowledgements

Funding for this work was provided by Central Institute of Fisheries Education (Indian Council of Agricultural Research) as institutional fellowship and contingent grant. We thank the faculty of regional centres of Central Marine Fisheries Research Institute and Central Institute of Fisheries Technology, who have helped to collect the data samples for this work.

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