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Morphometric and meristic analyses of Randall's threadfin bream *Nemipterus randalli* Russell, 1986 along the Indian coast

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ABSTRACT

Nemipterus randalli Russell, 1986 is one of the commercially important demersal fish in Indian waters. The present study was designed to understand the morphometric and meristic variations between the stocks of *N. randalli* along the Indian coast. A total of 450 samples were collected from 5 maritime states during September to November 2018. A total of 19 morphometric and 9 meristic traits were extracted and subjected to statistical analyses. Factor analysis showed that morphometric characteristics like eye diameter, head length, pre-pectoral length, post-orbital length, anal fin length and caudal peduncle depth were significant in separating the stocks. Discriminant function analysis showed a high re-classification success rate of 80.43%. Kruskal-Wallis test of meristic traits revealed lack of difference between the stocks. Results indicated the presence of different phenotypic stocks along the Indian coast and therefore the need for separate management strategies for sustaining the catch of *N. randalli* in the future.

Keywords: Demersal fish, Factor analysis, Management, Phenotypic plasticity, Stock

Stock identification is a central theme in fisheries science, which involves the study of self-sustaining components within natural populations (Cadrin *et al.*, 2014). It plays a critical role in fisheries management and forms the basis of stock assessment models. Fish stocks are identified based on differences in stock characteristics. Environmental, temporal and spatial features can be used to differentiate the stock of a particular species. Detailed information is needed to distinguish between the stocks to warrant separate management practices, especially with the fish populations having complex spatial structures due to larval dispersal. The information on stock structure of fish combined with the life history parameters should be utilised to develop management strategies and promote judicious exploitation of fish species (Jennings *et al.*, 1998; Denney *et al.*, 2002).

The differences in the phenotypic traits may allow us to differentiate the stocks even when their geographical distribution overlaps (Swain and Foote, 1999). Morphological characters such as morphometrics and meristic have been traditionally involved in fisheries biology to describe various categories of fish (Utter, 1981). These characters have been frequently employed in the stock delineation of fish (Silva, 2003; Sajina *et al.*, 2013). Morphometric characters show ontogenic changes associated with allometric growth, which is influenced by environmental parameters (Gould, 1966), whereas,

meristic differences between fish stocks may be influenced by genetic or environmental parameters or both, in unknown proportions (Swain *et al.*, 2005). As long as environmental factors are taken into account in the stock identification findings, the use of non-genetic techniques should not be questioned (Campana and Casselman, 1993).

Threadfin breams are one of the significant contributors to the demersal fisheries of India. It contributed nearly 4.29% (1.53 lakh t) of the total marine catch and they are mainly targeted by trawls (CMFRI, 2020). *Nemipterus japonicus* and *Nemipterus randalli* are the two major nemipterid species commonly landed along the Indian coast. The Nemipterids have gained commercial importance due to their high flesh content, good flavour, presence of white meat and wide use for the preparation of surimi and surimi-based products (Rajesh *et al.*, 2014). Fish stock characterisation and correct taxonomic identification of species are fundamental for successful fisheries management. However, only limited studies have been conducted on the stock identification of *N. randalli* (Joseph and Jayasankar, 2001). Hence, the present study was undertaken to analyse the stock variation in *Nemipterus randalli* Russell, 1986 based on the morphometric and meristic analyses from the samples collected along the Indian coast.

Samples of *N. randalli* (N=450) were collected from Maharashtra (Mumbai), Goa (Mormugao) and Kerala (Kochi) from the west coast and Tamil Nadu (Thoothukudi) and Andhra Pradesh (Visakhapatnam) from the east coast of India between September to November, 2018 (Fig. 1; Table 1). Locations were identified based on the availability of samples and sufficient latitudinal separation. The specimens were washed, cleaned and placed on a graph sheet to provide calibration and the images were captured with a digital camera. The images (.jpg) were converted to .tps format with tps Util (Rohlf, 2006a) and they were digitised with landmarks using tpsDig2 V2.1 (Rohlf, 2000b). Subsequently, a total of 19 morphometric measurements *viz.*, total length (TL), standard length (SL), fork length (FL), head length (HL), pre-orbital length (PrOL), eye diameter (ED), post-orbital length (PoOL), upper jaw length (UJL), pre-dorsal length (PDL), dorsal fin base length (DFBL), pre-pectoral length (PPrL), pectoral length (PrL), pre-pelvic length (PPcL), pelvic

length (PcL), inter-pelvic anal length (IPAL), pre-anal length (PAL), anal fin base length (AFBL), caudal peduncle depth (CPD) and maximum body depth (MBD), were extracted using Paleontological Statistics Software Package for Education and Data Analysis (PAST) (Hammer *et al.*, 2001) (Fig. 2). The size-dependent variation was removed by adopting the widely accepted formula given by Elliot *et al.* (1995).

$$M_s = M (L_s/L_o)^b$$

where, 'M' is the original morphometric measurement, 'M_s' is the morphometric measurement after size correction, 'L_s' is the overall mean of the standard length of all the samples, 'L_o' is the standard length of the fish and 'b' is the slope of the regression of log M on log L_o. A total of 9 meristic traits were extracted from the left lateral aspect of the fish following the widely accepted criteria given by Hubbs and Lagler (1958).

Table 1. Details of *N. randalli* samples collected from various locations along the Indian coast

Coast	East		West		
	Thoothukudi	Visakhapatnam	Kochi	Mormugao	Mumbai
Location	Thoothukudi	Visakhapatnam	Kochi	Mormugao	Mumbai
Month of sampling	September, 2018	September, 2018	October, 2018	November, 2018	October, 2018
No. of samples	100	100	100	50	100
Total length (cm)	19.76±0.03	18.29±0.19	10.35±0.12	12.51±0.09	17.94± 0.17
(mean and range)	(16.48-24.88)	(13.50-22.70)	(9.33-15.60)	(10.39-13.72)	(14.58-24.26)

*Values in parentheses indicates the sample size after the removal of outliers

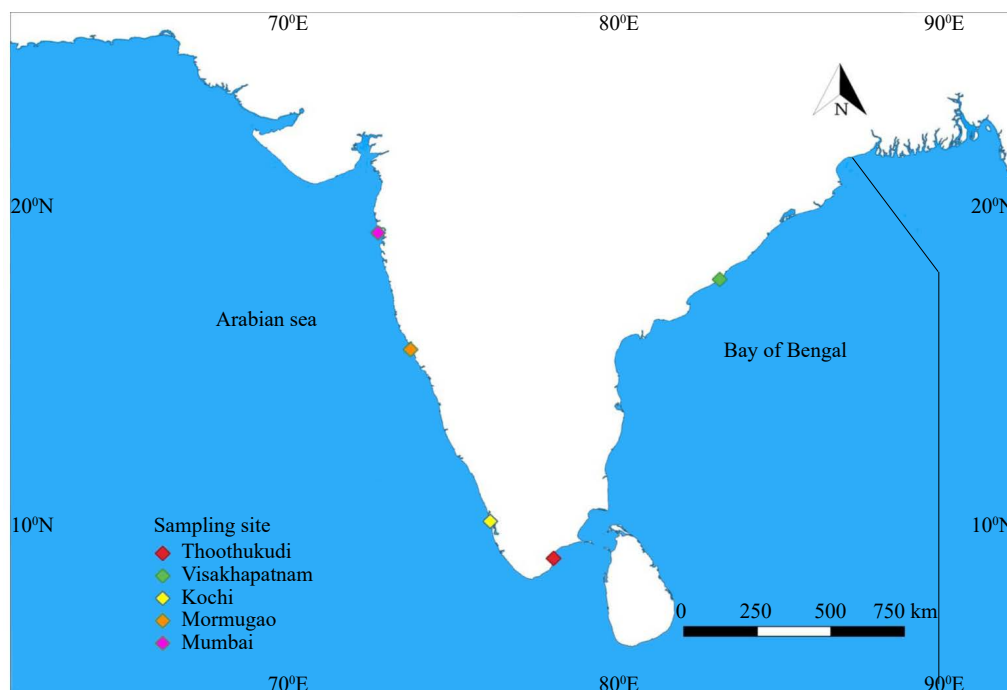


Fig. 1. Map depicting sampling locations of *N. randalli*

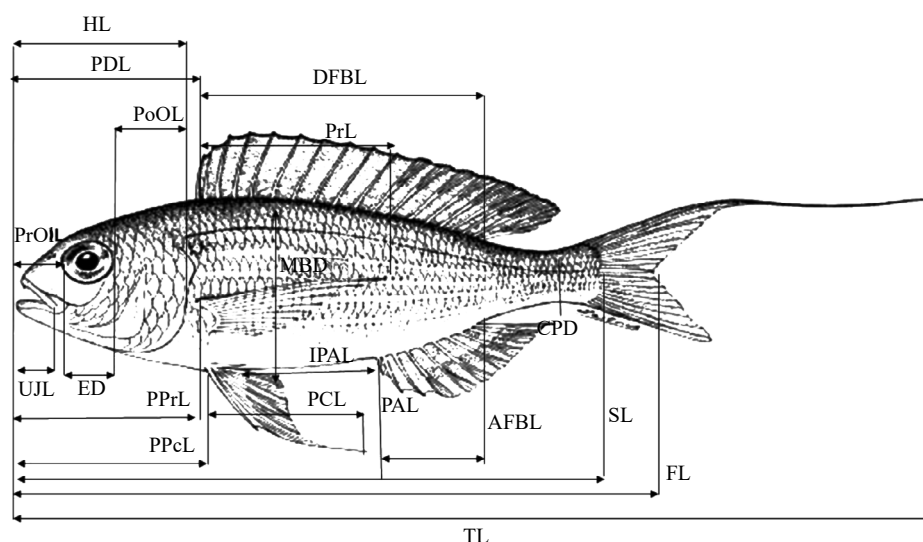


Fig. 2. Morphometric traits of *N. randalli* used in present study

The data were checked for normality and the outliers (n=36) were removed. The morphometric traits were analysed for the difference between the sampling stations using multivariate analysis of variance. The meristic data were subjected to non-parametric Kruskal-Wallis test. Further, the transformed morphometric data were subjected to factor analysis with the principal component method, a data reduction technique commonly used to identify the variables contributing to the variation between the stocks. Discriminant function analysis was used to classify and categorise each specimen to their respective locations based on the factors with higher loadings. All the statistical analyses were done using STATISTICA 12 (Statsoft, 2012)

Multivariate analysis of variance found a significant difference between the samples collected from the 5 different sites along the Indian coast for the extracted morphometric traits ($p < 0.05$). The initial 4 factors of the factor analysis together explained 66.68% of the total variations from morphometric characters. The first, second and the third factors contributed to 32.09, 14.08 and 12.31% of the total variation, respectively. Factor 1

was highly loaded on the eye diameter, head length and pre-pectoral length. High loadings of factor 2 and factor 3 are associated with post-orbital length, caudal peduncle depth, inter pelvic-anal length and anal fin length. The bivariate plot based on the factor scores of morphometric variables showed overlapping of Mumbai and Kochi stocks. Further, Thoothukudi and Visakhapatnam stocks showed demarcation between them (Fig. 3). The discriminant analysis conducted with the factor loadings of more than 0.7 showed the highest classification rate of 80.43% between the locations. The highest percentage of classification was seen in Mormugao stock (Table 2).

The spine and ray count of dorsal, anal, pelvic fins and the branchiostegal rays were constant among all the sampled locations. Analysis of meristic characters indicated that *N. randalli* possessed 10 dorsal fin spines, 9 dorsal fin rays, 3 anal fin spines, 7 anal fin rays, 1 pelvic fin spine and 5 pelvic fin rays with 6 branchiostegal rays. The species had 15-17 pectoral fin rays and 45-48 lateral line scales and the Kruskal-Wallis test revealed lack of significant difference between the sampling stations of these meristic traits ($p > 0.05$) (Table 3).

Table 2. Percentage of fish classified to their respective locations by discriminant analysis

Sampling site	Mumbai	Mormugao	Kochi	Thoothukudi	Visakhapatnam
Mumbai	88.88	1.11	5.55	2.22	2.22
Mormugao	0	97.67	0	2.32	0
Kochi	15.62	4.16	67.70	9.37	3.12
Thoothukudi	4.34	3.26	15.21	67.74	9.67
Visakhapatnam	1.08	0	3.26	5.43	90.21
Total rate of classification (%)	82.45				
Total rate of misclassification (%)	17.55				

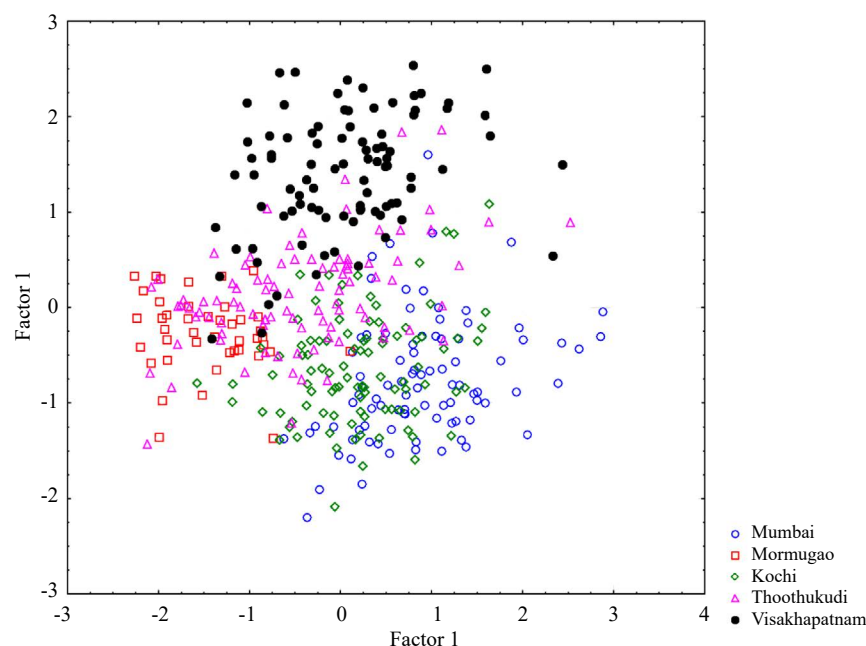


Fig. 3. Scatterplot of factor 1 and factor 2 scores from the morphometric traits of *N. randalli*

Table 3. Summary of meristic traits of *N. randalli* sampled along the Indian coast. Values include range, mode, significance value of the Kruskal-Wallis test and the comparison of meristic traits with published literature

Meristic traits/ Location	Mumbai	Mormugao	Kochi	Thoothukudi	Visakhapatnam	p-value Kruskal-Wallis test	Murty (1978)	John and Hameed (1983)	Golani and Sonin (2006)
Dorsal fin spines	10 (10)	10 (10)	10 (10)	10 (10)	10 (10)	-	10	10	10
Dorsal fin rays	9 (9)	9 (9)	9 (9)	9 (9)	9 (9)	-	9	9	9
Anal fin spines	3 (3)	3 (3)	3 (3)	3(3)	3 (3)	-	3	3	3
Anal fin rays	7 (7)	7(7)	7 (7)	7(7)	7(7)	-	7	7	7
Pectoral fin rays	16 (15-17)	16 (15-17)	16 (15-17)	16 (15-17)	16 (15-17)	0.28	16-18	15-16	15-16
Pelvic fin spine	1(1)	1(1)	1(1)	1(1)	1(1)	-	1	1	1
Pelvic fin rays	5 (5)	5 (5)	5 (5)	5 (5)	5 (5)	-	5	5	5
Branchiostegal rays	6 (6)	6 (6)	6 (6)	6 (6)	6 (6)	-	-	-	-
Lateral line scales	45(45-48)	45(45-48)	46 (45-48)	47(45-48)	46 (45-48)	0.33	45-49	45	46

* $p < 0.05$

The present study indicated the presence of different stocks of *N. randalli* along the Indian coast. The difference in the phenotypic characters might be due to geographical separation (Murta *et al.*, 2008). In this study, the significant differences between the stocks were mostly contributed by the eye diameter, head length and caudal peduncle. These characters also contributed to the variations in the stocks of *N. japonicus*, sampled from the Indian coast, which is a confamilial species and occupies the same ecological niche (Sreekanth *et al.*, 2015). Both the Arabian Sea and the Bay of Bengal have their peculiar environment features based on upwelling, salinity and current velocity

(Rao *et al.*, 1992; Kumar *et al.*, 2010). These prevailing environmental conditions play a major role in altering the morphometric traits of respective stocks (Murta, 2000).

Differences in the eye diameter between the stocks may be due to the intensity of light in their habitat during the early developmental stages of fish (Matthews, 1998). A massive influx of sediments from the major Indian rivers into the Bay of Bengal indicates the minimal penetration of solar radiation (Kumar *et al.*, 2010). Hence, variation in eye diameter in fishes from east and west coasts of India could be attributed to the variation in light

penetration and the associated adaptive development of the species. The difference in the caudal peduncle region of fish stocks along the Indian coast has been observed earlier in various studies (Sajina *et al.*, 2013; Sreekanth *et al.*, 2015). Imre *et al.* (2002) concluded that the difference in the morphology of the caudal peduncle region of Brook charr was due to the differences in the water velocity. The Bay of Bengal, known for its high-water turbulence than the Arabian Sea, might result in the phenotypic variation in the caudal peduncle. Gatz (1979) suggested that the head-related morphometric traits variations may be due to the differences in prey size. Site-specific differences in the food and feeding biology of *N. randalli* have been previously reported (Raje, 1996; Zacharia and Nataraja, 2003; Joshi, 2005).

Meristic characters are generally set early in the ontogeny and remain constant throughout the lifetime. Our present study indicated lack of plasticity between the meristic traits of *N. randalli* stocks along the Indian coast. Previous studies on the meristic characteristics of *N. randalli* from Kakinada (Murty, 1978), Kochi (John and Hameed, 1983) and the Mediterranean Sea (Golani and Sonin, 2006) reported results similar to the present study. Meristic characters of *N. japonicus* (Sreekanth *et al.*, 2013) and *N. bipunctatus* (Vaisakh, 2013) do not reveal any difference between the stocks along the Indian coast. Hauser and Ward (1998) suggested that the mixing of a few fishes per generation might result in a lack of genetic differentiation. Since there is no geographical barrier between the sampling sites, the lack of differences in the meristic traits might be due to the gene flow between the populations.

It is evident from the present study that there are different phenotypic stocks of *N. randalli* present along the Indian coast. Demographics and stock assessment studies have to be separately conducted for the stocks to provide a stock-specific management advisory. Further, the findings from our present study warrant investigation using molecular markers in order to arrive at a conclusion on the stock structure of *N. randalli* along the Indian coast.

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