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Stock structure analysis of Splendid ponyfish *Eubleekeria splendens* (Cuvier, 1829) along Indian coast using truss network system

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Eubleekeria splendens (Cuvier, 1829) also called Splendid ponyfish, is commercially important and has wide distribution along the Indian coast. The species shows dominance along the south-west and south-east coast but there is no detailed information on the stock structure available from Indian waters. Therefore the present study focused on understanding the stock structure based on putative spawning stock. Fish samples were collected from five locations: Three from the west and two from the east coast. Twenty-four morphometric variables were measured using a box-truss network method. Principal component analysis delineated the population into east and west coast stocks. With respect to locations, each sampling unit formed separate clusters, thus representing isolated stocks. The samples from Mangaluru produced a single clustering with Kozhikode samples indicating that the morphological profiles of these two populations are homogeneous. Multiple comparisons on the factor scores indicated two independent stocks on the east coast, whereas the fishery on the west coast is replenished by a single stock on south-west coast but a separate stock on the north-west coast. Thus, information on the spatial structure of phenotypic stock makes it mandatory to understand the biology and dynamics of these isolated stocks of *E. splendens* separately and thereby a traditional stock assessment should be performed to estimate current resource status stock-wise in terms of biological reference points.

[**Keywords**: Splendid ponyfish; Truss network; Phenotypic stock; Spatial structure]

Introduction

In tropics, demersal stock constitutes the multitude of species occurring in the same fishing ground. There are no discontinuities separating young from adult, reproductive stages from reproductive stocks[1]. The species assemblage in the region of which stocks are the part are the peak communities, the outcome of [illegible]

subgroup of population called the stock; is a sub-set of one species having the same growth and mortality parameters, inhabiting a particular geographical area and sharing a common gene pool[3].

The present study focused on the Splendid ponyfish, *Eubleekeria splendens* (Cuvier, 1829) (Order-Perciformes, Family-Leiognathidae), a common benthopelagic species in the coastal and estuarine waters of the tropical oceans[4]. It forms an important component of the demersal marine fisheries of several countries and exploited in the coastal fishing grounds in the Indo-Pacific and the Western Central Atlantic Oceans[4]. The peak occurrence of leiognathids is in shallow waters at a depth of about 25 m[1].

Leiognathids has been reported as one of the common by-catch species in tropical shrimp trawlers in south-east Asian countries. They are smaller in size (<20 cm), form benthic assemblages and are often [illegible][5]. This leads to large [illegible] en shrimp is the target species. There has been a decline in silverbellies resources by 0.27 lakh tonnes (23.6%) from 2015[6]. Thus, it is likely that "recruitment overfishing" may occur in addition to the "growth overfishing" due to the indiscriminate trawling and use of small mesh sizes gears. Demersal groups are embedded in a complex ecosystem where they perform their role as consumers and prey of other organisms[1]. It is an ecologically important group, being a prey item for commercially important demersal groups and large pelagics with wide distribution along the Indian coast.

However, there is no information on the stock structure of this species from Indian waters. This study aimed to provide a comparative analysis of morphometric variations based on body shape using truss network system[7, 8] from five regions where they are currently being caught by commercial fishing trawlers.

Materials and Methods

Study area

A total of 344 specimens of *E. splendens* were collected from populations in five different regions along the Indian coast (*i.e.* Mangaluru, Kozhikode and Veraval along the west coast and Chennai and Rameshwaram along the east coast) between December 2015 and February 2016 (Fig. 1). The sampling period coincides with the peak spawning season of the fish, thus avoiding the mixing of putative stocks[9]. Only fully mature specimen (to avoid sex biasness) with no distortion were selected for the present study. The sampling locations, sex ratio and the range of standard length (SL) are shown in Table 1. The image of specimens were photographed using a Sony Cyber Shot DSC-W300 digital camera for reproducibility and only one side of the specimen (*i.e.* left side) was captured to avoid variations due to bilateral asymmetry.

Morphometric analysis

A total of 13 anatomic landmarks were defined (Table 2, Fig. 2) corresponding to hard structures mostly distributed along the fish body contour, to archive the body shape with minimum errors[10]. Twenty-four truss variables (Fig. 3) were measured from the fish specimens, based on 13 anatomical landmarks obtained following the truss network protocol[11]. A step-wise procedure was followed:

Positioning: A graph sheet was placed on a thin thermocol board, with the thawed fish placed on top. The body posture was stretched to its natural position for measurements on the left side of the specimen.

Pinning: Long rounded pins were pierced through the thermocol board to locate the anatomical landmarks on the body of the fish and also to keep the fins in their natural position in the digitized specimens.

Digitizing: Each specimen was labelled with a specific code to identify it. A cybershot DSC W300 digital camera (Sony, Japan) with the resolution of 50X was used for capturing the images. Digital

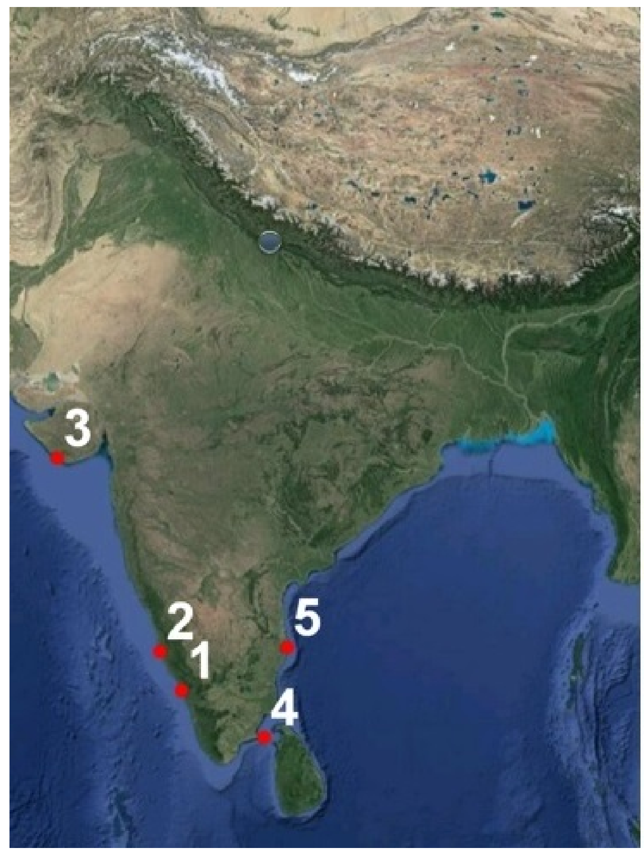

Fig. 1 — The mark-ups indicate the locations from where fish samples were collected for this study.

Table 1 — Details of the sampling locations for *E. splendens* along the Indian coast.

Sampling Station	GPScoordinates	Sample size	Source of catch	Sex ratio	Mean (SL ± SD)
Kozhikode	Lat. 11°19’06.8”N Long. 75°44’40.0”E	70	Single day trawlers	1: 0.90	07.35 ± 0.059
Mangaluru	Lat. 12°51’41.5”N Long. 74°49’57.1”E	64	Single day trawlers	1: 0.64	07.11 ± 0.118
Veraval	Lat. 20°54’22.1”N Long. 70°23’00.8”E	70	Single day trawlers	1: 0.70	11.10 ± 0.0938
Rameshwaram	Lat. 9°16’46.1”N Long. 79°12’20.2”E	70	Artisanal catch via gillnet	1: 0.84	07.51 ± 0.0648
Chennai	Lat. 13°07’40.1”N Long. 80°18’02.4”E	68	Single day trawlers	1:1.00	08.14 ± 0.0695

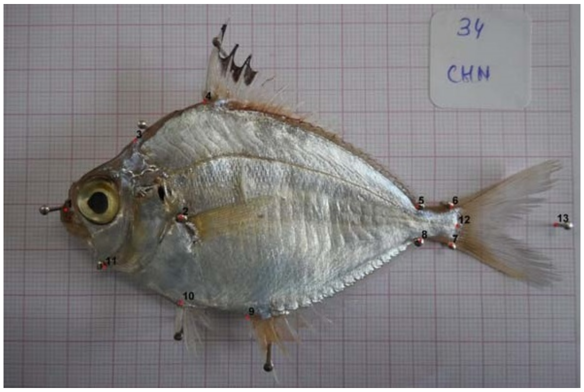

Fig. 2 — Locations of 13 anatomical landmarks used for *E. splendens*

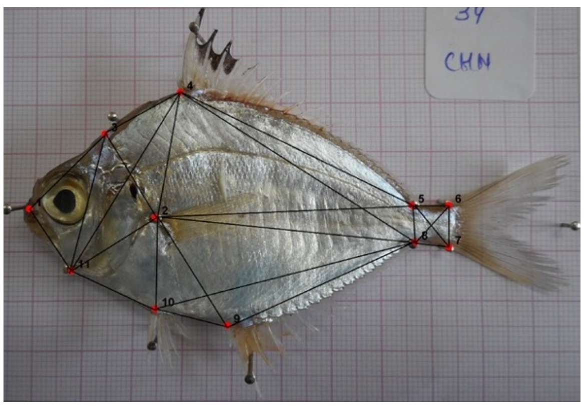

Fig. 3 — Truss network system based on 24 distances for *E. splendens*

records of specimens provide the opportunity to repeat measurements and reproduce results if required[12].

Networking: The tpsDig Version 2.1[13] program allows placing landmarks on the two dimensional images and record scale factors, saving the data as tps file. Further, the Paleontological Statistics software (PAST)[14] was used to extract distances between landmarks that are recorded as x-y coordinates. The variables measured are described in Table 2 and marked in Fig. 3. All the computation and statistical analyses were carried out using the SPSS Version 16[15] and PAST version 3.10[14]

Identification of sex

After recording the landmarks, the specimens were dissected to identify their sex. To account for sexual dimorphism (presence of luminescent organs near the oesophagus in males) with respect to their morphometric characters, the sex of each specimen was taken into consideration. Females were identified by the presence of an oval-shaped ovary with eggs. Males were identified by the presence of paired oval testis as a creamy white mass[6]. Since the identification of phenotypic stocks is based on separate spawning populations, only samples with mature gonads were used for the present study.

Table 2 — List of truss distances used for analysis of *E. splendens*.

Truss variables	Description
1-3	Anterior tip of snout to base of nauchal depression
1-11	Anterior tip of snout to base of opercular opening
2-3	Base of pectoral fin to base of nauchal depression
2-4	Base of pectoral fin to origin of dorsal fin
2-5	Base of pectoral fin to base of end of dorsal fin
2-8	Base of pectoral fin to base of end of anal fin
2-9	Base of pectoral fin to origin of anal fin
2-10	Base of pectoral fin to origin of pelvic fin
2-11	Base of pectoral fin to base of opercular opening
3-4	Base of nauchal depression to origin of dorsal fin
3-11	Base of nauchal depression to base of opercular opening
4-5	Origin of dorsal fin to base of end of dorsal fin
4-8	Origin of dorsal fin to base of end of anal fin
4-11	Origin of dorsal fin to base of opercular opening
5-6	Base of end of dorsal fin to origin of the upper caudal fin
5-7	Base of end of dorsal fin to origin of the upper caudal fin
5-8	Base of end of dorsal fin to base of end of dorsal fin
6-7	Origin of the upper caudal fin to origin of the lower caudal fin
6-8	Origin of the upper caudal fin to origin of the upper caudal fin
7-8	Origin of the lower caudal fin to base of end of anal fin
8-9	Base of end of anal fin to origin of anal fin
8-10	Base of end of anal fin to origin of pelvic fin
9-10	Origin of anal fin to origin of pelvic fin
10-11	Origin of pelvic fin to base of opercular opening

Statistical analysis

The multivariate data obtained was first tested for outliers and distortion of the general tendency in the multinomial size distribution. Thus, the Mahalanobis distance[16] was measured for estimating outliers using SPSS software. The multinomial Mardia's test[17] was used to determine whether the data follows a multivariate normal distribution. Since variations should be imputable to body shape differences, they should not be related to the relative size of the fish[18]. Correlations were used to determine the effect of size on truss variables and if significant, the size-effect was removed by employing an allometric approach as per as formula[19],

$$\mathbf{M_{trans} = M\,(SL_{mean} / SL)^{b}}$$

Where,

- M trans is the transformed truss measurement,
- M is the original truss measurement,
- SL the standard length of fish,
- SL mean the overall mean standard length,
- b is the within-group slope regressions of the log M against log SL.

*SL is used to avoid the handling issues related to caudal fin distortions.

The transformed data were once again examined using correlation against SL to see whether the size effect had been removed *($p>0.01$)* (Table 3).

To determine which size-adjusted truss distances can most effectively differentiate phenotypic populations, the contributions of variables to principal component analysis (PCA) were examined. PCA[19] is an empirical model based on the set of uncorrelated composite variables called principal components (PCs) obtained from a correlation matrix. Each PC is a linear combination of all variables and is defined by an eigen vector and an eigenvalue, measuring the of variability explained by a few PCs. The transformed truss measurements were subjected to factor analysis (FA)[20], wherein data reduction technique helps to identify variables that form biologically meaningful groupings with significant contribution to the retained factor components. It is used in theoretical research following a maximum likelihood method to extract the factor components in SPSS ver.16. Further, a few factor components were retained for rotation procedure (varimax rotation) and this was based on the cumulative proportion of variances and scree plot. The rotation procedure in a truss variable is said to load heavily on a given factor if the factor loading is 0.4 or greater[21].

To test the effect of coast, locations (within a coast) and sex (to check the effect of sexual dimorphism if any), the Multivariate Analysis of Variance

Table 3 — Correlation coefficient of original and statistically adjusted truss variables (cm) in E. splendens; 1) Between standard length and original truss variables (p <0.001) represented as italic values; 2) size adjusted (bold values) truss measurements (p >0.005).

	Parameters	1 to 12		1 to 3		1 to 11	
	Pearson Correlation	1.000	1	.682**	-.032	.184**	-.071
	Sig. (2-tailed)			.000	.564	.001	.203
	Parameters	1 to 13		2 to 3		2 to 5	
	Pearson Correlation	.996**	-.010	.380**	-.046	.631**	-.212**
	Sig. (2-tailed)	0.000	.852	.000	.411	.000	.000
	Parameters	2 to 5		2 to 8		2 to 9	
	Pearson Correlation	.868**	-.043	.772**	-.101	.948**	-.004
	Sig. (2-tailed)	.000	.443	.000	.070	.000	
	Parameters	2 to 10		2 to 11		3 to 4	
	Pearson Correlation	.034	-.090	-.002	-.074	.909**	.007
1-12 (Standard length)	Sig. (2-tailed)	.543	.105	.970	.183	.000	.905
	Parameters	3 to 11		4 to 5		4 to 8	
	Pearson Correlation	.890**	.005	.725**	-.082	.706**	-.094
	Sig. (2-tailed)	.000	.900	.000	.144	.000	.094
	Parameters	4 to 11		5 to 8		5 to 7	
	Pearson Correlation	.717*	.014	-.107	-.140*	-.143**	-.144**
	Sig. (2-tailed)	.000	.823	.055	.012	.010	.009
	Parameters	5 to 8		6 to 7		6 to 8	
	Pearson Correlation	-.103	-.115*	-.112*	-.130*	-.107	-.121*
	Sig. (2-tailed)	.064	.039	.045	.020	.055	.030
	Parameters	7 to 8		8 to 9		8 to 10	
	Pearson Correlation	.700**	-.034	.644**	-.141*	.636**	-.197**
	Sig. (2-tailed)	.000	.541	.000	.011	.000	.000
	Parameters	9 to 10		10 to 11			
	Pearson Correlation	.736**	-.096	.303**	-.059		
	Sig. (2-tailed)	.000	.085	.000	.293		

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

(MANOVA)[22] was applied to the rotated factor scores from FA. MANOVA has greater power to detect an effect compared to a series of ANOVAs since the former can detect whether groups differ along a combination of variables. The multiple comparisons based on factor scores using box plot was done graphically to demonstrate the difference among the sampled population from various locations. The truss distances with high factor loading were further subjected to step-wise Discriminant Function Analysis (DFA) [23]. It primarily classifies individual specimens to putative stocks representing their locations with no prior knowledge. The classification success rate is evaluated based on percentage of individuals correctly assigned into original sampling location[24] and then calculating the proportion of correctly allocated individuals.

Results

A total of 20 observations were identified as outliers (based on Mahalanobis distance) and removed from the data. The multinomial Mardia's test signified that the data follow a multivariate normal distribution (*p<0.001*). Significant correlations were observed between the body size and the morphometric variables (*p<0.001*). The size-effect was removed employing an allometric approach, and after size correction, all correlation coefficients for truss variables decreased to values below 0.1(*p >0.005)* (Table 3).

Between the locations

The first principal component accounted for 63.34% and the second accounted for 27.25% cumulatively accounting for 90.60% of the variations in truss measurements data. PC-I scores were plotted against PC-II scores to see morphometric variations between the sampling locations (Fig. 4). Each sampling unit formed separate clusters, thus representing isolated stocks with respect to their geographical locations. However, the samples from Mangalore produced a cluster mixing up with samples from Kozhikode indicating that the morphological profiles of these two populations are homogeneous.

The factor analysis of the transformed variables explained 83.59% of the total morphometric variation with percentage contribution of 73.83% and 9.76 % on the first and second factor, respectively. The first and second factors were chosen for rotation based on eigenvalues (Table 4). After rotating the first and second factors, the characters belonging to the middle

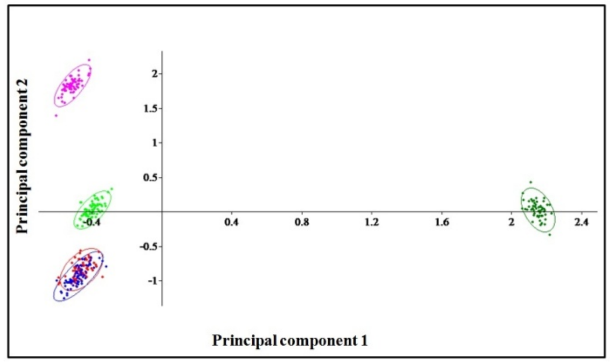

Fig. 4 — Scatter plots of the individual scores on the principal components of truss characters for *E. splendens* with respect to sampling locations. (: Kozhikode, : Mangaluru, : Veraval, representing west coast : Rameshwaram, : Chennai representing east coast).

Table 4 — Rotated factor matrix of factor 1 and 2 showing loading for truss variables

Truss variables	Factor 1	Factor 2
4-8	0.994	
2-4	0.993	
4-5	0.989	
2-8	0.989	
2-5	0.923	0.367
5-7	-0.89	0.434
7-8	-0.88	0.437
6-7	-0.88	0.459
6-8	-0.88	0.449
2-11	-0.86	0.469
5-6	-0.85	0.484
2-10	-0.82	0.556
1-11	-0.692	0.597
2-9		0.949
3-4		0.905
1-3		0.831
2-3	-0.6	0.688
10-11	-0.615	0.663
7-8		0.634

portion of the body (below the first dorsal din) loaded heavily on the first factor, *i.e.* distances 2-4, 2-5, 2-8, 4-5, 4-8, 5-7, 5-8 and 6-7 (Fig. 5a) while measurements associated with the region along the head region loaded significantly on the second factor, *i.e.* distances 1–3, 2-9, and 3-4 (Fig. 5b). The loading of factor 1 and 2 are given in Table 4.

Multiple comparisons based on factor scores

When factor scores were plotted for locations within a coast, separations were observed between locations except Mangalore and Kozhikode (Fig. 6a & 6b). Multiple comparison tests on factor 1 showed that the samples from Kozhikode and Mangalore on the west coast belonged to single stock (Fig. 6a).

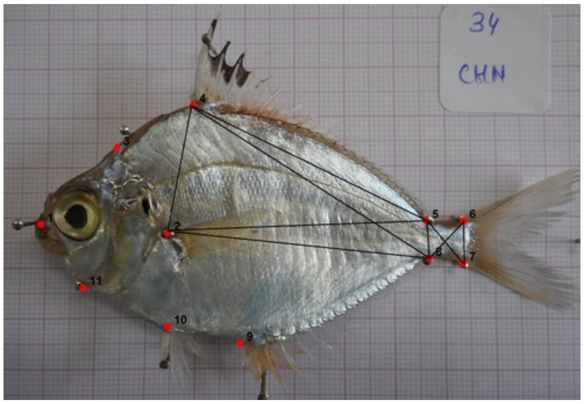

Fig. 5a — Loadings of first factor scores on body shape of *E. splendens*.

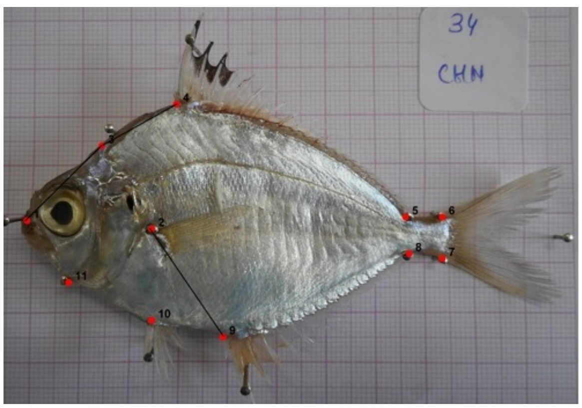

Fig. 5b — Loadings of second factor scores on body shape of *E. splendens*.

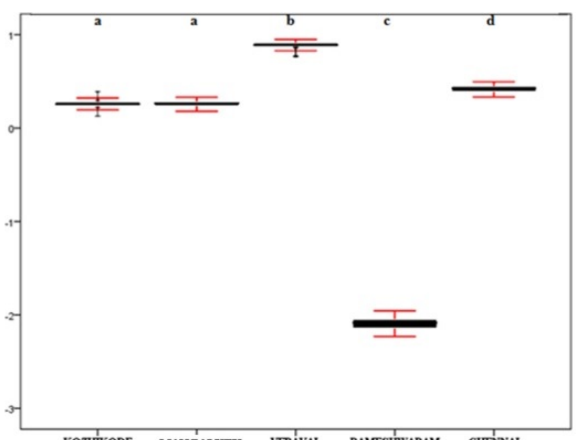

Fig. 6a — Box plots of factor 1 representing sampling locations. Locations with same superscript in a graph indicate no significant difference from each other ($p \leq 0.001$).

Significant difference between the samples obtained from locations within the west coast as well as east coast and, hence, they may represent a separate stock. Multiple comparison tests for scores on factor 2 also showed the same results (Fig. 6b).

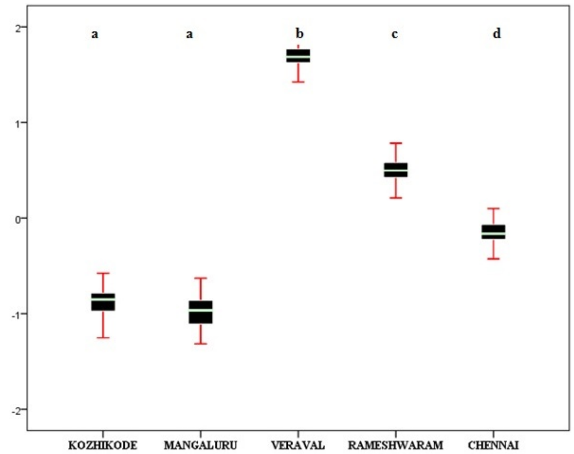

Fig. 6b ─ Box plots of factor 2 representing sampling locations. Locations with same superscript in a graph indicate no significant difference from each other ($p \leq 0.001$).

Multivariate Analysis of Variance (MANOVA): The MANOVA on scores of factor 1 and 2 indicated significant effect for locations within the east and west coasts as well as between the coast. But, there was no significant difference with respect to sex, inferring shape differences not related to sexual dimorphism (Table 5).

Discriminant analysis: The variables loaded heavily on the first and second factor axes were taken for classifying individuals between the five sampling locations and the coasts. Location-wise discriminant function analysis resulted in 86.3% of overall accuracy in classifying the observations to various locations *i.e.,* 65.7%, 68.8%, 100.00%, 100.00% and 100.00% for Kozhikode, Mangaluru, Veraval, Rameshwaram and Chennai samples, respectively (Table 6a).

Coast-wise discriminant function analysis resulted in 96.9% of overall accuracy in classifying the observations to various locations (96.4% for the east coast and 97.6% for the west coast samples) (Table 6b).

Discussion

The truss system had been used previously to investigate stock separation within a species. It allows in a long term, a better and direct comparison of morphological evolution of stocks using shape analysis[8,25]. The present study revealed significant distinction between the sub-populations of splendid ponyfish, *E. splendens* in terms of body shape along the Indian coast. The causes of morphological differences between sub-populations are often quite difficult to explain[26], but it is well known that

Table 5 — Effect, value, F value hypothesis degree of freedom and significant indicator of MANOVA. The effect of locations within a coast, sex and coast was tested using individual scores obtained from factor analysis of the truss morphometric variables.

MANOVA						
Effect		Value	F	Hypothesis df	Error df	Sig.
Location wise	Wilks' Lambda	.000	14295.001^{b}	8.000	632.000	0.000
Sex		.999	0.126	2.000	319.000	.882
coast wise		.028	354.762^{b}	29.000	292.000	.000

b. Indicate a significant difference for the effect(P≤.001)

Table 6a — Cross-validation of individuals between the locations using discriminant function analysis

LOCATION WISE(6a)		Predicted Group Membership				
		Kozhikode	*Mangaluru*	*Veraval*	*Rameshwaram*	*Chennai*
	Kozhikode	65.7	34.4	0.0	0.0	0.0
	Mangaluru	31.3	68.8	0.0	0.0	0.0
	Veraval	0.0	0.0	100.0	0.0	0.0
Cross-validated	*Rameshwaram*	0.0	0.0	0.0	100.0	0.0
	Chennai	0.0	0.0	0.0	0.0	100.0

87.0% of original grouped cases correctly classified.
86.3% of cross-validated grouped cases correctly classified.

Table 6b — Cross-validation of individuals between the coast using discriminant function analysis.

COAST WISE (6b)			Predicted Group Membership	
			West	*East*
Cross-validated	%	*West*	96.4	3.6
		East	2.4	97.6

97.2%of original grouped cases correctly classified.
96.9% of cross-validated grouped cases correctly classified

morphometric characters can show a high degree of plasticity in response to environmental conditions[27], for example, ecological interactions such as competition for food, space and shelter, predation pressure, anthropogenic activities such as overfishing, pollution, discards, and hydro biological factors such as water temperature and salinity.

Gene flow and environmental factors

The spatial distribution pattern of the individuals of the population among Kozhikode and Mangaluru has shown a pattern of migration within coincident environmental conditions, similarities in the genetic pool that remained during the evolution, or by the significant rate of interbreeding[28]. These morphometric differences, even if not caused by environmental factors[29], the significant rate of interbreeding between those locations would be sufficiently high, even environmentally induced differences are masked[30]. There is sufficient gene flow between the areas in each generation preventing genetic differentiation. It provides an insight into interaction between the spatial units with respect to their location and serves as a biological basis of the current stock.

Geographical isolation

The alignment of west (Kozhikode, Mangaluru and Veraval) and east (Rameshwaram and Chennai) coast stocks representing showed stock segregation. This could be due to geographical isolation along ecologically different environments that may have resulted in the development of significantly different morphological features between fish populations as geographical barrier reserved the flow of genetic exchange. Migration between areas is very likely to happen but the settlement of specimens in each area is probably long enough to adapt to the local environmental factors[31]. Such morphological differences among different populations of a species can also be related to differences in habitat factors, such as temperature, turbidity, food availability, water depth, and water flow[27,29,32]. Previous studies had shown that the northern and southern parts of Arabian Sea and Bay of Bengal hold significantly different ecological habitats in terms of salinity, water temperature and circulation patterns[25].

The Chennai and Rameshwaram are in proximity when compared to other sampling locations but yet two phenotypic stocks were found. Rameshwaram island (Lat. 9°17' N, Long. 79° 17'E) is a submerged chain of islands with Ramsethu of India and Mannar island of Sri Lanka acting as physical barriers between the Gulf of Mannar and the Palk Bay[33] (Fig. 7). The waters of Gulf of Mannar are transitional between the oceanic conditions of the Arabian Sea and coastal conditions of the Palk Bay[34]. The Gulf of Mannar has a narrow shelf and steeply sloping sea floor, which cause the oceanic waters flow closer to the coastline[35]. Thus, Gulf of Mannar waters possess intermediate characteristics of the Arabian Sea and the Palk bay[34]. It enjoys both the monsoons, the north-east and the south-west. With the onset of the south-west monsoon, the Gulf of Mannar becomes rough and choppy, while the Palk Bay is calm. During the north-east monsoon these conditions are reversed[36]. Thus, the unique hydro-biological, topographical conditions and current pattern of Rameshwaram waters results in the partial isolation with Bay of Bengal waters showing more similarity with Sri Lankan stocks than the Indian mainland, forming a unique fauna with respect to environmental conditions. The species is benthopelagic occurring in shallow waters and do not undergo extensive migration[1]. These biological characteristics are responsible for adaptation to local habitat and environmental conditions.

Similarly, the strong morphometric differentiation was observed between the Mandapam and Digha populations, in addition to considerable coral reef features of the Gulf of Mannar region, which suggests the existence of separate spawning stock populations of horse mackerel in these regions and might require distinct stock assessment programs to provide effective management strategies for the east coast[37].

Fig. 7 — Location of the Gulf of Mannar

Management and conservation measures

Marine fishery resources are renewable and exhaustible; hence the management and conservation of these resources are very essential for the sustained fish production from the seas. The commercial fishing, especially trawling, indiscriminately captures a number of species of various size groups including target catch, incidental catch and discarded catch and is one of the most urgent threats to the world's remaining fish stocks[38]. Silver bellies are one of vulnerable groups undergoing growth overfishing due to by-catch from major fishery groups like shrimp trawls, pelagic trawls and purse seines[39,40]. These gears contribute to by catch owing to their non-selectivity and results in capture of a huge quantity and diversity of non-target species[41] including juveniles and adults of silverbellies. Indiscriminate loss of this group can have a deleterious effect on the benthic habitat as it is associated fauna that provides food sources for a variety of important demersal fish species, play key roles in the marine food-webs that fortify ecosystem processes and functioning, thus, alters the structure of benthic communities which in turn determines the productivity of marine capture fisheries[42]. Presently, there is no specific management strategy for silverbellies due to its low economic value and multispecies nature of fishery. The routine mesh size regulation, uniform seasonal ban are implemented for all species. In relation with the present study, there is a need to manage phenotypically isolated subpopulation with unique evolutionary taxa, separately for conservation purposes. For this, first the biology, spatial distribution, population dynamics for each phenotypic group should be studied separately and an ecosystem based approach should be followed to formulate the management policies. Thus, information on the stock structure of a species is useful for applications ranging from determining appropriate conservation units to estimating the stock composition in mixed-stock fisheries[43].

Limitations and future studies

The present study indicates that the populations of splendid ponyfish have distinct sub-populations along the Indian coast. To visualize the spatial distribution and migration pattern, more sampling locations (nearby as well as distant) should be included in future study, based on species spatial and temporal distribution rather than on the basis of major landing areas. Trawling surveys should be conducted to validate the samples representing the population and species distribution with respect to the locations. A detailed study involving the molecular genetics and environmental aspects may further confirm the present findings. Being a by-catch species, they are undergoing tremendous pressure due to trawling, hence there is a need to understand the spatial and temporal integrity of the species which can be further used to validate the biology and population dynamics studies of the sub-groups of the species population. Further it can be helpful in fisheries management and resource sustainability.

Conclusion

An understanding of stock structure is vital for designing appropriate management regulations in fisheries where multiple stocks are exploited differentially. The present study addressed the presence of region-specific phenotypic stocks with significant rate of intermixing between Kozhikode and Mangaluru populations. Distinct fish stocks should be managed separately and the governing bodies should collaborate with each other to manage these fish stocks irrespective of political boundaries. The ecological importance of the small, by-catch and discard species has to be realised, since they are the linkage species to higher trophic levels in the ecosystem terms of the catch composition and energy transfer which share a percentage contribution to marine fish production of the world.

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