Indian Journal of Geo Marine Sciences
Vol. 47 (02), February 2018, pp. 381-389

Taxonomic differentiation of goatfishes (Family-Mullidae) based on morphological traits and hard parts

*Karankumar K. Ramteke, Asha T. Landge, A. K. Jaiswar, S. K. Chakraborty, G. Deshmukhe & Renjith R. K[1]

ICAR-Central Institute of Fisheries Education, Versova, Andheri (W), Mumbai - 400 061, India
[1]ICAR-Central Institute of Fisheries Technology, Kochi-682 029, India

[E.Mail: kkramteke@gmail.com]

Received 12 January 2016 ; revised 5 July 2016

A comparative evaluation of morphometric characters of goatfishes collected from different parts of India was conducted in order to discriminate them. Among the body ratios the proportion of body depth to standard length was found to be important that varied in the range of 11-39 %, with maximum (34-39 %) in *Upeneus guttatus* and minimum (11-26 %) in *U. moluccensis*. Among meristic characters number of dorsal fin spine differed, it was 8 in all the species except in *U. guttatus* where it was 7. Gill rakers present on lower limb of first arch were highest *in U. sulphureus, U. moluccensis, Parupeneus indicus* (18-22); lowest number was in *U. sundaicus* (13-15) followed by *U. tragula* (14-16). Highest numbers of lateral line scales were recorded in *U. taeniopterus* (36-38) and lowest in *U. guttatus* (28-30). Discriminant function analysis for ten morphometric characters gave misclassification of 0% for *P. indicus, U. guttatus, U. sulphereus, U. sundaicus, U.tragula, U.vittatus* and 3% for *U. moluccensis,* 6% for *U. taeniopterus*. Wedge shaped otolith (sagitta) was found in *U. guttatus* and *P. indicus,* oval in *U. sulphureus,* elliptic to truncate anteriorly in *U. vittatus*, fusiform and serrated margins in *U. moluccensis,* elliptic to truncate anteriorly for *U. sundaicus and U. taeniopterus*. Rostrum short, slightly flattened, antirostrum poorly defined in *U. tragula*. In *U. moluccensis* parietal crest was poorly developed. In *U. tragula* and *U. moluccensis,* pterosphenoid was not in direct contact with lateral ethmoid, and pterosphenoid joined to basisspenoid in *U. vittatus* and *U. guttatus*.

[Keywords: Morphology, Meristic, Otolith, Osteology and goatfishes.]

Introduction

Fishes, like many other forms of life, are of immense value to humans[1]. There are about 27,977 valid species of fishes[2]. Recent record indicates 33,200 fish species exists in the world[3]. The marine fish landing of India was 3.6 million tonnes during 2014. Demersal finfishes contributed 27% of the total landings of India where goatfishes contributed 4% of total demersal fish landing. The total landing of goatfishes in India was 34,575 tonnes[4]. Goatfishes (Family: Mullidae) are tropical marine fishes, associated with the reef. A total of 6 genera and 85 species are known worldwide[5], of which only 3 genera and 18 species are known from the Indian waters (Table 1).

Day[6] described 14 species of goatfishes but expressed doubts about the validity of some of the species described and suggested that a detailed study of the group was necessary to assess the correct systematic position of the species. Weber and de Beaufort[7] reported 28 species from Indo-Australian Archipelago including 3 species whose identity was not certain. Thomas[8] carried out a detailed study on the taxonomy of 19 species of goatfishes occurring in the seas around India. Talwar[9] compiled information on 20 species known to occur in Indian waters, based on work of Thomas[8].

Traditionally, the fish species are identified on the basis of morphological and meristic characters. The general morphometric and meristic characters are very useful characters for classification[7, 11-15], however there is a scope to explore the alternate characters, which can substantiate the morphological and meristic characters and give more acceptances to the identification procedures[10]. Osteological characters and otolith have been reported to be valuable for fish identification[16-24]. There has been considerable change in the systematic, taxonomy and nomenclature of species belonging to the goatfish family during last two decades.

Table 1. List of the species available in Indian Water.

Genus	Species
Mulloidichthys Whitley, 1929	*Mulloidichthys flavolineatus* (Lacepède, 1801)
	Mulloidichthys vanicolensis (Valenciennes, 1831)
Parupeneus Bleeker, 1863	*Parupeneus barberinus* (Lacepede, 1801)
	Parupeneus cyclostomus (Lacepede, 1801)
	Parupeneus heptacanthus (Lacepede, 1802)
	Parupeneus indicus (Shaw, 1803)
	Parupeneus macronemus (Lacepede, 1801)
	Parupeneus multifasciatus (Quoy and Gaimard, 1824)
	Parupeneus pleurostigma (Bennett, 1831)
	Parupeneus rubescens (Lacepede, 1801)
	Parupeneus trifasciatus (Lacepede, 1801)
Upeneus Cuvier, 1829	*Upeneus guttatus* (Day, 1868)
	Upeneus luzonius Jordon and Seale, 1907
	Upeneus moluccensis (Bleeker, 1855)
	Upeneus sulphureus Cuvier, 1829
	Upeneus sundaicus (Bleeker, 1855)
	Upeneus taeniopterus Cuvier, 1829
	Upeneus tragula Richardson, 1846
	Upeneus vittatus (Forsskal, 1775)

A basic constraint in the identification goatfishes is the very few meristic characters. One of the few useful meristic characters is the number of dorsal-fin spines, which requires thorough examination in order to see the minute, first spine in the eight-spine species group that distinguishes it from the seven-spine group[25-26]. Another important character is the number of pectoral-fin rays which may differ among species by one ray. Number of gill rakers is the useful traits in differentiation. This can be separated into various as per the position whether they are rudimentary or well-developed. Lateral-line scale counts are also useful, but they are most of the time lost during collecting and processing of sample. Also, in many species the scales it may be difficult to count the exact number of scales from entire body. This characters lead to considerable variation in scale counts[8].

Assumes greater importance in tropical seas where a multitude of closely resembling species occurs. The closely resembling species may vary widely in biological characteristics; hence the role of taxonomy cannot be overstressed in studies on population dynamics. Sometimes overlapping morphological characters among the closely related species posse difficulty in differentiation hence in collecting biological and catch data. In the present study an attempt has been made to study the taxonomy of goatfishes of India based on morphometric, meristic, osteological and otolith morphology.

Material and Methods

A total of 457 specimens belonging to 8 species of family Mullidae, were collected from Mumbai, Mandapam and Chennai coasts of India, during August 2011 to March 2012 in landings of commercial fishing vessels (Table 2). The species of goatfishes were identified using the diagnostic key described by Smith[27], Munro[28], Day[12], Fisher and Bianchi[28], Talwar and Kackar[9].

Table 2. List of material examined.

Species	Location	Length range(mm)	Sample size
Upeneus guttatus	Mumbai	140.2 - 184.4	24
Upeneus sulphureus	Mandapam	93.7 -222.7	40
Upeneus vittatus	Chennai, Mandapam	80 - 269.2	62
Upeneus moluccensis	Mumbai, Mandapam, Chennai	121.5 - 220.7	93
Upeneus sundaicus	Mandapam, Chennai	93.7 - 222.7	52
Upeneus taeniopterus	Mandapam	128.1 - 162.9	50
Parupeneus indicus	Mandapam	99.8 – 182	43
Upeneus tragula	Mandapam	85.4 - 252.9	51
	Total		415

A total of twenty morphometric (Table 3) and twelve meristic traits were measured by following Hubbs and Lagler [30]. The otoliths were extracted and washed thoroughly and the sun dried otoliths were stored in plastic vials for further study. Otoliths were imaged with a Leica Stereo zoom microscope configured with 1.25X lens and substage oblique illumination. For osteological study the tissues from specimens were cleared and stained following Hollister[19] and Clothier[31]. To determine morphological variations among goatfishes the data generated on morphometric and meristic characters were subjected to multivariate analyses. The size dependent variation was removed using an allometric approach of Reist[33] with some modification i.e., location wise SLmean was considered in the place of overall mean. Morphometric distances are continuous variables and therefore, appropriate for conventional multivariate analyses. All of the measurements were log transformed and tested for normality using the SAS PROC UNIVARIATE procedure and the outliers were removed before further analysis.

Significant correlations were observed between the body size and the morphometric variables and hence, the variation in the whole data may discriminate the populations based on size of the fish[33]. Therefore, the absolute morphometric variables were first transformed into shape variables that are size independent. This was employed using an allometric approach using the following formula.

All individual morphometric data were thus transformed, using the following equation of allometric approach of Reist[33] with modification to remove size dependent variation.

$$M_{trans} = \log M - \beta (\log SL - \log SL_{mean})$$

Where,

M*trans* - transformed measurement

log M – natural log transform of the original measurement

β - within-all species group slope regressions of the log M vs log SL

SL - standard length of the fish

SLmean - species-wise mean of the standard length.

The transformed data was analysed in order to delineate the species

Factor analysis was carried out to know which factors loading and the factor found to be highest loadings were subjected to Stepwise discriminant function analysis using PROC STEPDISC[31] procedure to determine the important morphometric variables to discriminate the species. Step disc is usually applied first then the significant loadings are used in factor analysis.

The discriminant function analysis was carried out by considering the scratched factors from factor analysis using PROC DISCRIM procedure of SAS. Discriminant Function Analysis (DFA) on morphometrics and meristics were performed to identify the characteristics those were important in distinguishing population groups in the pooled sample. A discriminant function analysis was employed to calculate the probability of correct classification of each fish to its species.

PROC MEANS procedure[31] was used to estimate the descriptive statistics. The estimates recorded were minimum, maximum of the meristic traits. PROC FREQ[31] procedure was used to create frequency distribution table for number of dorsal soft rays, number of gillrakers on lower arch and number of lateral line scale.

Results

Morphometric

The multivariate test of equality of groups, after data were standardized for size by using an allometric approach[33], was performed. Transformed data was subjected to factor analysis. The characters loaded on the first, second and third factor of the factor analysis were taken for the step wise discriminant function analysis (Table 4). Out of those factors, six characters are length related (MTL, MPDL, MPAL, MPCL, MPVL, MAL) and other four characters are not related to length (MED**,** MDFB1, MDFL1, MBD) generally STEP Discrim is done to find the significant variables. Those significant variables are again treated for factor analysis. Which help to avoid non-significant variables from entering in the analysis Discriminant function analysis performed on the above characters revealed misclassification of 0% for *P.indicus, U.guttatus, U.sulphereus, U.sundaicus, U.tragula, U. vittatus* and for 3% for *U. moluccensis,* 6% for *U. taeniopterus* (Table 5).

Meristic

Number of spines in the first dorsal fin was constant (8) for all species except in *Upeneus guttatus* where it was 7. Number of soft pectoral rays present varied between 12 and 18. Number of pectoral soft rays found to be highest (13-18) for *U. moluccensis*, while lowest (12-14) for *U. taeniopterus* and *U. tragula*. However, first dorsal finrays (8), second dorsal fin spine (1) and pelvic fin spine (1), pelvic rays (5), anal rays (6), and caudal finrays (15) were noted to be constant in all eight species of goatfishes. Number of gillrakers present on lower limb of first arch was observed to be highest *in U. sulphureus, U. moluccensis* and *Parupeneus indicus* (18-22). While lowest was observed in *U. sundaicus* (13-15) followed by *U. tragula* (14-16). Number of lateral line scales were noted to be highest in *U. taeniopterus* (36-38) while lowest was observed in *U. guttatus* (28-30).

Otolith

The comparative study of the gross morphology of otolith sagitta extracted from eight species have shown variations (Fig.1).

Upeneus guttatus Shape: wedge shaped, anterior region with only one conspicuous, well developed tip that forms a clearly acute angle. Posterior region: oblique, more or less straight or regularly curved. Otolith margins: crenate; section of margin, wavy forming more or less conspicuously round.

U. sulphureus Shape: oval, anterior region; rostrum short, very broad, blunt; posterior region: round to oblique, otolith margin: wavy forming more or less conspicuous round

U. vittatus Shape: elliptic, anterior region: peaked, posterior region: oblique irregular, otolith margins: margin composed of conspicuous, round tipped projections.

U. moluccensis Shape: fusiform, anterior region: with only one conspicuous, well developed tip, rostrum moderately long, posterior region: oblique, more or less straight, otolith margins: margin or parts of margin composed of conspicuous, differently shaped, irregularly spaced protuberances.

U. sundaicus Shape: elliptic, anterior region: very wide, short tip, which forms an almost straight or obtuse angle, posterior region: more or less straight, otolith margins: wavy forming conspicuous round and superficial crenulations.

U. taeniopterus Shape: elliptic, anterior region: blunt, posterior region: flattened-oblique, otolith margins: dentate, part of margin composed of conspicuous round tipped and more or less fused Projections.

U. tragula Shape: round to slightly flattened, anterior region: rostrum broad, short, pointed to round. posterior region: oblique, otolith margins: composed of conspicuous and irregularly spaced protuberances

Parupeneus indicus Shape: wedge shape, anterior region: prolonged and progressively narrower, ending in a flat tip, posterior region: more or less regular curve with an approximately median or submedian Apex. Otolith margins: regularly, wavy more or less conspicuous

Osteology

The skull features have been found to be very useful in differentiation of closely related species of fishes. Hence the same was also used to differentiate the species of family Mullidae.

Lateral Ethmoid In all eight species of family Mullidae, viz., *Parupeneus indicus, Upeneus vittatus, U. tragula, U. sulphureus, U. moluccensis, U. sundaicus*, *U. guttatus* and *U. taeniopterus*, the premaxilla (Fig. 2,3A& 3B) consisted of comparatively less broad lateral ethmoid, and outer margin was gently curved outwardly. While in *U. taeniopterus* and *U. sundaicus,* it was straight and medially articulated with ethmoid**.**

Frontal: Covers more than three fourth of the roof of the skull. Frontal possess a single ridge, formed as a result of the union with the parietal crest posteriorly and run forward laterally and terminates near the anterior limit of the orbit: it does not take part in the formation of pterotic ridge except in *P. indicus.*

Parietal: Parietal crest is well developed in all species except in *U. moluccensis*.

Epiotic: In *U. vittatus, U. tragula, U. sulphureus, U. moluccensis, U. guttatus* and *U. taeniopterus* epiotic is pyramid shaped, bifurcated, connected with the pterotic laterally, but in case of *P. indicus* and *U. sundaicus*, it is single.

Pterosphenoid: Pterosphenoid joins the basisspenoid, contact with lateral ethmoid separated by frontal, joins the basisspenoid. Hence there is no direct contact with lateral ethmoid in *U. tragula* and *U. moluccensis*.

Discussion

In the present study analysis of important characters such as proportion of head length, eye diameter, pre orbital length, body depth, pre anal fin length, anal fin base, caudal peduncle length to the standard length and total length for 8 of goatfishes species was able to differentiate them. The proportions of head length to standard length were similar for *Upeneus guttatus*, *Upeneus vittatus* (25-27%). The proportion of head length to standard length in fishes belong to genus *Upeneus*, is comparatively less than in genus *Parupeneus*. Species of genus *Parupeneus* are associated with coral reef unlike the species of genus *Upeneus* hence variation in head length may be related with habitat used by them. Gatz[32] also opined that the variation in head characters may reflect differential habitat use and head length may be related to prey size.

The variation in eye diameter can be attributed to the developmental changes in their early stages corresponding to the light intensity in their habitat and it may reflect differences in turbidity of habitat[36]. The proportion of eye diameter to head length was similar for *U. guttatus, U. sundaicus* (21-27%). In *U. vittatus* proportion of eye diameter to head length was found out lowest in range (14-25%). Hence the variation in eye diameter in goatfishes found in the present study may be attributed to the variation in light penetration, resultant light intensity and associated adaptive development in the species.

Variation in meristic characters has been used as basic tool in separating populations of different fish species as studied by Seymour[37] and Anthony and Boyar[38]. Based on number of pectoral soft rays counts *P. indicus* has been apparently differentiated from *U. tragula* and *U. taeniopterus.* This finding is supported by Fischer and Bianchi[29] and Thomas[8] (1969). On the basis of the number of gillrakers present on lower limb of first arch, *U. sundaicus* clearly differentiated from the *U. taeniopterus, U. moluccensis, U. vittatus* and *P. indicus* but shown overlapping with *U. tragula* and *U. guttatus.* Variation in number of gillrakers within species was significantly greater in tropical species as reported by Moodie[39]. The difference in number of gillrakers is related to the difference in inter raker spacing as observed by Amundsen *et al.*, [40]. This difference in also associated with food availability that resembling a specific feeding habit and development of feeding apparatus especially gillrakers.

Variation in the morphology of otolith sagittae in 8 species of Mullidae was also observed. In *U. guttatus* and *P. indicus* otolith was Wedge shape, cuneiform and elliptical shaped in *U. vittatus, U. moluccensis, U. sundaicus, and U. taeniopterus*. Shape of otolith was oval in *U. sulphureus* and angled in *U. tragula*. According to Nolf and Sterbaut[41] otolith shape and size is considered as species specific and the phylogenetic patterns can be reflected in their morphology.

Consequently, otolith morphology can be used to establish phylogenetic relationships. Nevertheless, the combination of otolith shape with other types of data may help clarify these relationships among species.

The neurocranium in all the species was found to be triangular, narrow at the anterior and broad posterior. Supraoccipital crest was well developed and was carried forward by the close opposition of the dorsal elevated rim of the frontals. The epiotics were pyramid-shaped. Sphenotic forms the roof of the orbit posteriorly. The length of the snout was a little longer in *Parupeneus* than other species, as also reported by Thomas[8]. Frontal bone of the skull projecting downward which is associated with the lateral ethmoid and parasphenoid in all eight species studied.

Large variations in osteological characters of the lateral ethmoid, frontal, parietal, opiotic, and pterosphenoid have been observed among the mullid species. This study will help future workers to some extent in the study of phylogenetic relationship within goatfishes. Finally, correct identification of species will help in formulating correct management strategies.

Table 3.A.Descriptive statistics of morphometric traits (mm) of *Upeneus moluccensis, Upeneus guttatus, Parupeneus indicus, U. sulphureus*

	Upeneus moluccensis		***Upeneus guttatus***		***Parupeneus indicus***		***U. sulphureus***	
Traits	Min (mm)	Max (mm)	Min (mm)	Max (mm)	Min (mm)	Max (mm)	Min (mm)	Max (mm)
TL	121.5	220.7	140.2	184.4	99.8	182	93.7	222.7
SL	101.5	188.1	116.39	153.3	83.4	151	79	190
HL	23.49	50.4	31	40	23.2	41.8	20	46
PrOL	5.16	16.2	8.68	13.46	10.18	21	6.41	16
PoOL	10.89	23	9.67	15	8.2	14.5	9.81	23.07
PDL	30.30	66.4	32.85	48.35	48	87.4	29	73
PPcL	30.6	57.5	30.55	44	29	49.16	27	73
PPvL	29.6	49	30.59	46.5	27.06	48.9	27	64.63
PAL	65.7	125.1	74.6	94.8	52.4	95.5	58.5	138
IDS	12.5	25.4	15.63	22	6.7	12	12.31	37
DFB1	14.4	30.2	17	27	14.5	24.25	13.53	33
DFL1	16.2	40.1	20.12	27.48	12.1	24	16	51
DFB2	11.9	24.2	15	22	11.9	21.2	10.78	26
DFL2	11	22.9	16.24	24	11.9	21.9	8.02	18.97
PcL	19.9	43.1	27.2	48	17.3	32	16	42
PvL	11.5	26	16.43	27	14.4	30	9.1	30
AL	10.6	19.7	11.68	15.04	9.7	18.68	8.63	27
BD	14.9	48.8	42.69	55	22.4	50	22.28	61
CPD	8.9	19.1	11	14.75	8.8	16.36	8.96	27
ED	6.8	8.5	7	9.4	4.8	8.9	5.4	8.1

Table 3.B.Descriptive statistics of morphometric traits (mm) of *Upeneus sundaicus, Upeneus taeniopterus, Upeneus tragula, Upeneus vittatus*

	U. sundaicus		*U. taeniopterus*		*U. tragula*		*U. vittatus*	
Traits	Min (mm)	Max (mm)	Min (mm)	Max (mm)	Min (mm)	Max (mm)	Min (mm)	Max (mm)
TL	94	222.7	128.1	162.9	85.4	252.9	80	269.2
SL	78.5	190	110	140	74.26	225	70	233
HL	19	46	24.52	40	16.3	55.25	18	59.96
PrOL	6.41	16	7.68	9.7	6.2	18	5	17
PoOL	9.81	23.07	10.26	12.9	7.4	21.8	8.34	28.06
PDL	29	73	33.06	42	23.1	69.3	23.5	79.7
PPcL	27	73	30.06	41	20.9	61.5	21.6	71
PPvL	27	64.63	30.52	41.86	3	71	21.1	70.9
PAL	58.5	138	67.2	90	44.5	132.5	44.9	149.1
IDS	12.31	37	12	17	10.4	29	7.5	27.7
DFB1	13.53	33	16.9	21.42	10.2	31.1	12.1	39.5
DFL1	16	51	20.58	26.14	10.5	27.18	14.6	49.4
DFB2	10.78	26	16.02	20.28	12.16	29.8	9.1	30.5
DFL2	8.02	18.97	13.6	17.56	8.9	25.4	9.7	31.7
PcL	16	42	18.82	23.86	15	44.44	16.3	53.7
PvL	9.1	30	14.98	18.98	7.9	34.7	10.4	34.4
AL	8.63	27	11.56	33.16	7.1	22.1	7.8	25.8
BD	22.28	61	27.1	38	14.9	47.4	17.64	59.22
CPD	9	26	12.54	15.92	8.5	25.1	6.8	22.8
ED	5.5	8.2	5.96	7.16	4.6	8.2	4.2	9.7

Table 4. Results of stepwise discriminant function analysis based on the transformed data.

Step	**Entered**	**Partial R-Square**	**F Value**	**Pr > F**	**Wilks' Lambda**	**Pr < Lambda**	**Average Squared Canonical Correlation**	**Pr > ASCC**
1	**TL**	0.9367	649.24	<.0001	0.06327734	<.0001	0.13381752	<.0001
2	**PDL**	0.9285	567.59	<.0001	0.00452493	<.0001	0.26546350	<.0001
3	**BD**	0.7350	120.82	<.0001	0.00119929	<.0001	0.36354305	<.0001
4	**PAL**	0.7032	102.91	<.0001	0.00035591	<.0001	0.46178620	<.0001
5	**AL**	0.6375	76.11	<.0001	0.00012903	<.0001	0.54866267	<.0001
6	**DFB1**	0.4101	30.00	<.0001	0.00007611	<.0001	0.59882576	<.0001
7	**DFL1**	0.4013	28.82	<.0001	0.00004557	<.0001	0.63345563	<.0001
8	**PVL**	0.3708	25.26	<.0001	0.00002867	<.0001	0.67248299	<.0001
9	**PCL**	0.3940	27.77	<.0001	0.00001737	<.0001	0.70012756	<.0001
10	**ED**	0.1842	9.61	<.0001	0.00001417	<.0001	0.70813677	<.0001

TL-Total Length **PDL**-Pre Dorsal length **BD**-Body Depth **PAL**-Pre anal length **AL**-Anal fin Length **DFB1**-First Dorsal fin Base **DFL1**-First Dorsal fin length **PVL**-Pelvic Fin Length **PCL**-Pectoral fin Length **ED**-Eye Diameter

Table 5. Results of discriminant analysis classification showing the percentage of specimens classified in each group

From Species	***P.indicus***	***U.guttatus***	***U.moluccensis***	***U.sulphereus***	***U.sundaicus***	***U.taeniopterus***	***U.tragula***	***U.vittatus***	**Total**
Parupeneus indicus	**43**	0	0	0	0	0	0	0	43
	100	0	0	0	0	0	0	0	100
Upeneus guttatus	0	**24**	0	0	0	0	0	0	24
	0	**100**	0	0	0	0	0	0	100
U.moluccensis	0	0	**90**	0	**1**	0	0	**2**	93
	0	0	**96.77**	0	**1.08**	0	0	**2.15**	100
U.sulphereus	0	0	0	**40**	0	0	0	0	40

	0	0	0	**100**	0	0	0	0	100
U.sundaicus	0	0	0	0	**52**	0	0	0	52
	0	0	0	0	**100**	0	0	0	100
U.taeniopterus	0	0	0	0	**3**	**47**	0	0	50
	0	0	0	0	**6.67**	**93.33**	0	0	100
U.tragula	0	0	0	0	0	0	**51**	0	31
	0	0	0	0	0	0	**100**	0	100
U.vittatus	0	0	0	0	0	0	0	**62**	62
	0	0	0	0	0	0	0	**100**	100
Total	43	24	90	40	56	47	51	64	415
	10.36	5.78	21.68	13.49	11.11	11.32	12.28	15.42	100

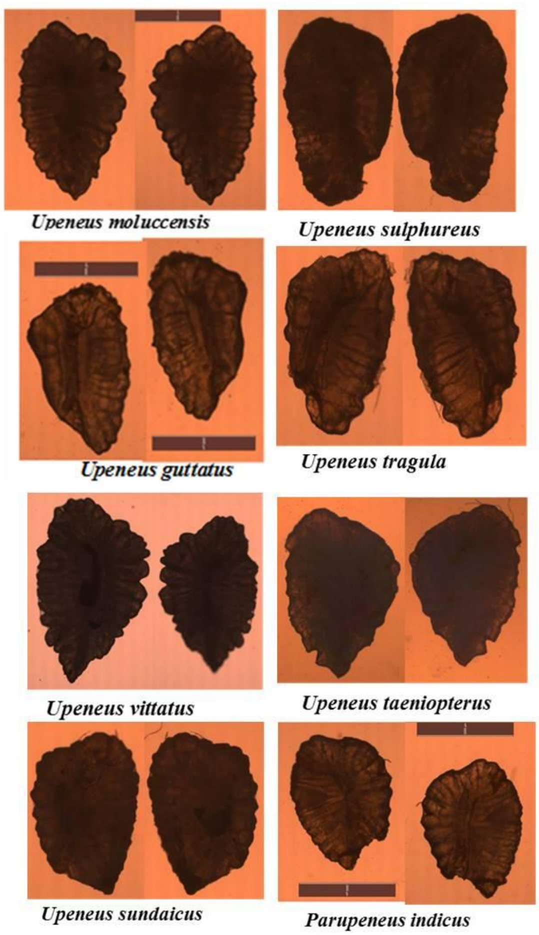

Fig.1: Ventral and dorsal view of Otolith sagittae of species of Mullidae

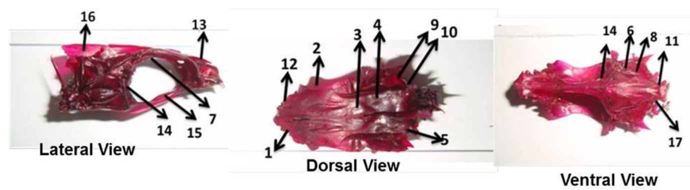

Fig.2: General description of nerocranium

Paired

1. Nasal
2. Lateral ethmoid
3. Frontal
4. Parietal
5. Epiotic
6. Sphenotic
7. Pterosphenoid
8. Prootic
9. Pterotic
10. Intercalar
11. Exoccipital

Unpaired

12. Prevomer
13. Ethmoid
14. Basisphenoid
15. Parasphenoid
16. Supraoccipital
17. Basioccipital

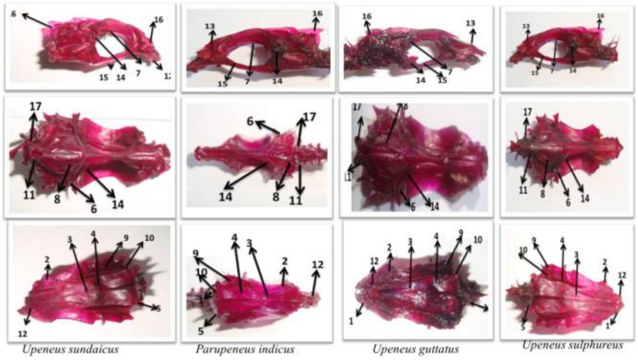

Fig.3A. comparative study of neurocranium *Upeneus sundaicus, Parupeneus indicus, U. guttatus and U. sulphereus*

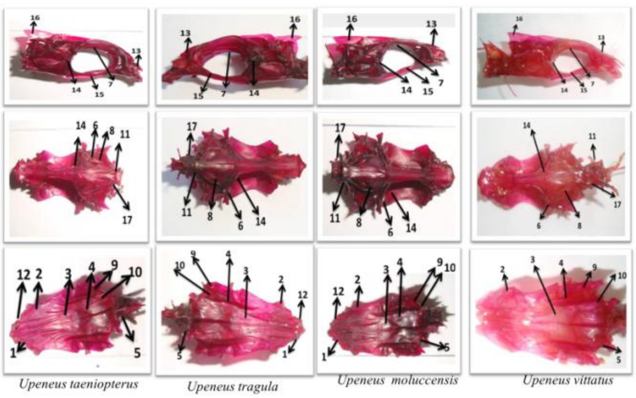

Fig.3B. comparative study of neurocranium *Upeneus taeniopterus, Upeneus tragula, U. moluccensis and U. Vittatus*

Acknowledgement

Authors are grateful to Director, ICAR-Central Institute of Fisheries Education, Mumbai for providing facilities and encouragement to carry out the above research work.

References

1. Sarwade, J. P. & Khillare, Y. K. Fish Diversity of Ujani Wetland, Maharashtra, India. *The Bioscan* (2010): 173-179.
2. Nelson, J. S., (*Fishes of the World* John Wiley & Sons, New York) 2006 pp.600.
3. FishBase. World Wide Web electronic publication. www.fishbase.org, (08/2015) Froese, R. and D. Pauly. Editors. 2015.
4. CMFRI. Annual Report 2014-15. Central Marine Fisheries Research Institute, Cochin, (2015). pp353.
5. Eschmeyer, W.N., Catalog of fishes. Updated database version of May 2005. Catalog databases as made available to FishBase in May 2005 (accessed 20 March 2012)
6. Day, F., *The fishes of India: being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma, and Ceylon. Volume 1*. William Dawson & Sons Ltd., London, 1875 pp.168.
7. Weber, M. & L.F. De Beaufort., The fishes of the Indo-Australian Archipelago. VI. Perciformes: Serranidae, Theraponidae, Sillaginidae, Emmelichthyidae, Bathyclupeidae, Coryphaenidae, Carangidae, Rachycentridae, Pomatomidae, Lactariidae, Menidae, Leiognathidae, Mullidae. A.J. Reprints Agency, New Delhi, (1931)6:448.
8. Thomas, P. A., Goatfishes (family Mullidae) of the Indian seas. *Mar. biol. Ass. India. Memoir-3*, 1969. pp.174.
9. Talwar, P.K. & Kacker, R.K., *Commercial sea fishes of India* (Zoological Survey of India) 1984 pp. 997.
10. Negi, R. K. Johal, M. S. and Rawal, Y. K., Ultrastructure of the Scale of Hillstream Fish, *Schistura montanus* (Mcclelland) and Its Phylogenic Significance. *The Bioscan* 5(3) (2010) 395-397.
11. Gunther, A., *Catalogue of the Acanthopterygian fishes in the collection of British Museum.* I: 1859.pp.524.
12. Day, F., *The fishes of India; being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon.* Vols. I & II. (Reprinted by Today and Tomorrow Book Agency, New Delhi, India) 1878. pp 778.
13. Herre, A. W. C. T. & Montalban.H. R., The Goatfishes, or Mullidae, of the Philippines. *The Phil. J. of Sci.* v. 36, no. 1, (1928) 95-137.
14. Turan, C., Phylogenetic relationships of Mediterranean Mullidae species (Perciformes) inferred from genetic and morphologic data. *Sci. Mar.*, 70(2); (2006)311-318.
15. Sreenivasan, P. V., On two new records of carangid fishes from Indian seas. *Indian J. Fish*, 21 (1) (1974) 20-28.
16. Boulenger, G. A., Fishes (Systematic Account of Teleostei). In *The Cambridge Natural History* Edited by S. F. Harmer and A. E. Shipley, Chapt. 7, (1904) 541-727.
17. Whitehouse, R. H., The caudal fin of the Teleostomi. *Proc. Zool. Soc*. London: (1910) pp.590-627.
18. Regan, C. T., The classification of the percoid fishes. *Ann. Mag. nat. Hist.*, ser. 8, 12(1913): 111-145.
19. Hollister, G., Clearing and dyeing fish for bone study. *Zoologica*, 12, (1934) 9-100.
20. James, P. S. B. R., Comparative osteology of the fishes of the family Leiognathidae, Part I. Osteology. *Indian J. Fish.*, 32(3) (1985): 309-358.
21. Taniguchi, N., Comparative osteology of the Sciaenid fishes from Japan and its adjacent waters-II. Vertebrae. *Jap.J. Ichthyol.*, 16(2): (1969).55-67.
22. Marathe, V.B. & Pashine, R. G., Observation on the chondrocronium of *labeo rohita*. *J.Biol.Sci.* 15; (1972)85-93.

23. Liu, H. C., Early Osteological Development of the Yellow Tail *Seriola dumerili* (Pisces:Carangidae) *Zool. Stud.* 40(4): (2001) 289-298.
24. Gnanamututtu, J.C., Osteology of the Indian Mackerel, *Rastrelliger kanagurta* (Cuvier). *Indian J. Fish*, 13 (1966) (1 and 2)1-26.
25. Lachner, E. A., A revision of the goatfish genus *Upeneus* with descriptions of two new species. *Proceedings of the United States National Museum* 103(1954) pp. 497–532.
26. Kim, B. J. & Nakaya K., Upeneus australiae, a new goatfish (Mullidae: Perciformes) from Australia. *Ichthyol. Res.* 49(2002)pp. 128–132.
27. Smith, J. L. B., *The sea fishes of Southern Africa* (Central News Agency, Ltd., South Africa) 1949 pp.580.
28. Munro, I S. R, *The marine and fresh water fishes of Ceylon*. (Halstead press Sydney) 1955 pp.349.
29. Fischer, W. and Bianchi, G., *Species Identification Sheets for Fishery Purposes. Western Indian Ocean (Fishing Area 51).* Prepared and Printed with the Support of the Danish International Development Agency (DANIDA). FAO, Rome, (1984).Vol. 1-6.
30. Hubbs, C.L. & Lagler, K.F., *Fishes of the Great Lakes region*. (*Univ. Mich. Press. Ann, Arbor,* Mich) 1958 pp.213
31. Clothier, C.R., A key to some southern California fishes based on vertebral characters. *Ibid*, 79, (1950) 3-83.
32. Humphries, J.M., Bookstein, F.L., Chernoff, B., Smith, G.R., Elder, R.L. & Poss, S.G., Multivariate discrimination by shape in relation to size, *Syst. Zool*., 30(1981) 291-308.
33. Reist, J. D., An empirical evaluation of several univariate methods that adjust for size variation in morphological data. *Can. J. Zool.*,63, (1985)1429–1439.
34. SAS Institute, SAS/STAT. User's Guide, Version 9.2, 4 thed. Vol. 1. (*SAS Institute*, Th *Cary, NC*)2008 pp. 943.
35. Gatz, A. J., Ecological morphology of freshwater stream fishes. *Tulane stud. zool. bot.,* 21, (1979). 91–124.
36. Matthews, W. J., Morphology, habitat use, and life history. In: *Patterns in Freshwater Fish Ecology* (Chapman & Hall, New York) 1988 pp.756.
37. Seymour, A., Effects of temperature upon the formation of vertebrae and fin rays in young chinook salmon. *Trans. Am. Fish. Soc,* 88, (1959) 58-69.
38. Anthony, V. C., & Boyar H. C., Comparison of meristic characters of adult Atlantic herring from the Gulf of Maine and adjacent waters. *Res. Bull. int. Comm. Northw. Atlant. Fish.* No. 5, (1968) 91-98.
39. Moodie, G.E., Gill raker variation and the feeding niche of some temperate and tropical freshwater fishes. *Environ. Biol. Fishes,* 13(1) (1985) 71-76.
40. Amundsen, P. A., Born, T. & Vaga, G.H., Gill raker morphology and feeding ecology of two sympatric morphs of European whitefish (*Coregonus lavaretus*) *Annls. Zool. Fennici.*, 41 (2004), 291-300.
41. Nolf, D. & Sterbaut E., Evidence from otoliths for establishing relationships within Gadiforms , in: Papers on the Systematics of Gadiform Fishes Edited by D.M. Cohen (*Natural History Museum of Los Angeles County Science* Series 32, Los Angeles) 1989, pp. 89–111.