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Occurrence of longfin goatfish *Upeneus supravittatus* (Uiblein and Heemstra, 2010) along Chennai coast, south India

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ABSTRACT

Goatfishes (Family: Mullidae) are commercially important fishery resource along the Chennai coast, south-eastern India. Species-level identification of goatfishes is a challenge, particularly in the '*vittatus'* group, as there is severe overlap of taxonomic characteristics. In 2010, Uiblein and Heemstra revised the Family Mullidae and reported the occurrence of *Upeneus supravittatus* along the Indian coast. They also remarked that *U. supravittatus* has been misidentified as *U. taeniopterus* in earlier reports from India. To resolve this and verify the occurrence of *U. supravittatus*, 15 morphometric characteristics and 13 meristic characteristics of goatfish samples collected at Chennai were analysed and compared with the corresponding data reported by Uiblein and Heemstra for *U. taeniopterus* and four other '*vittatus*' group goat fishes. The analysis, as well as DNA bar coding and area of distribution of species confirmed the samples as *Upeneus supravittatus*. The gill raker count on the upper and lower limbs of first gill arch was an important key in identifying the species. Though the number of gill rakers was almost similar for *U. supravittatus*, *U. vittatus* and *U. taeniopterus*, the size and position of the gill rakers confirmed that the collected samples were all *U. supravittatus.* The study also indicates the possibility that *U. supravittatus* has been hitherto wrongly reported as *U. taeniopterus.* A detailed taxonomic study on the Family Mullidae needs to be undertaken along the Indian coast using morphometric and meristic characteristics and DNA barcoding to resolve these taxonomic issues.

Keywords: DNA barcoding, Gill rakers, Species identification, '*vittatus'* group

Introduction

Goatfishes (Family: Mullidae) are commercially important in trawl catches from the coastal waters of the Indian seas (22,705 t in 2019 contributing 0.62% of total fish landings (CMFRI, 2019). In Chennai, 1201 t of goatfishes were landed by trawlers during 2019, of which the longfin goatfish *Upeneus supravittatus* (Uiblein and Heemstra, 2010) formed 28.9%.

Based on the taxonomic keys provided by Day (1878), Thomas (1969) and Kumaran and Randall (1984), seven species of goatfishes belonging to genus *Upeneus*, namely *U. sulphureus, U. moluccensis, U. tragula, U. vittatus, U. sundaicus, U. bensasi* and *U. taeniopterus* were recorded along Chennai coast (Vivekanandan *et al*., 2003). Recently a single specimen of *U. vittatus* (29 cm total length and 360 g total weight) has been reported from Pamban, Gulf of Mannar by Remya *et al.* (2021). According to this report, even though the Gulf of Mannar is known to be rich in goatfish abundance and diversity, the occurrence of *U. vittatus* in the commercial fish trawl landings is rare. Uiblein and Heemstra (2010), in their review on genus *Upeneus* identified 16 valid species namely *U. davidaromi, U. doriae, U. guttatus, U. mascareinsis, U. moluccensis, U. oligospilus*, *U. pori, U. sulphureus, U. sundaicus, U. taeniopterus*, *U. tragula* and *U. vittatus* including four new species, namely, *U. indicus, U. margarethae, U. suahelicus* and *U. supravittatus* in the Western Indian Ocean.

The review of genus *Upeneus* by Uiblein and Heemstra (2010) indicated a possibility that the commonly occurring and commercially important *U. supravittatus* was being misreported under the names of two species, namely, *U. taeniopterus* and *U. vittatus* along Chennai coast, due to a high level of overlapping of morpho-meristic characteristics among the three species as well as with other species of the genus *Upeneus*. A sound knowledge on the taxonomy of fishes contributing to the fishery and the capability to identify them to the species level plays a vital role in fisheries (Abraham *et al.*, 2011). To confirm the occurrence of *U. supravittatus*, a study on the morphometric and meristic characteristics of *U. supravittatus* was undertaken from samples collected in Chennai.

Materials and methods

Fresh specimens of *U. supravittatus* (n=100) were collected from trawl landings at Madras Fisheries Harbour (MFH) (12°80'N; 80°20'E) during 2019. The fresh specimens were brought to the laboratory and examined. The colour, meristic counts and morphometric

measurements of the fresh specimens were recorded. The samples were then preserved in formalin for 15 days and checked for retention of dark first dorsal fin tip, caudal fin bars and lateral body stripes. The recorded characteristics were then compared with the corresponding characteristics published by Uiblein and Heemstra (2010) for *U. supravittatus* sp. nov., *U. suahelicus* sp. nov., *U. indicus* sp. nov., *U. vittatus* and *U. taeniopterus*.

Each morphometric characteristic, when analysed separately, showed a wide range of values, that overlapped within all the species of '*vittatus'* group, leading to confusion in species confirmation. To overcome this confusion, the frequency of overlap of each value falling within the value range of a particular species was summed up and plotted below the value range of that species. The highest frequency of overlapping (HFO) was considered as the benchmark for confirming that species. The value of the body depth of first dorsal fin (BODYDD) of 17 specimens had values within the range of 22-25% of Standard Length (SL) (characteristic of *U. taeniopterus*); 65 specimens had values within the range of 25-29% SL (characteristic of *U. vittatus*) and 49 specimens had values within the range of 26-30% SL (characteristic of *U. suahelicus* and *U. supravittauts*). The HFO of the BODYDD characteristic was recorded for *U. vittatus* (65 specimens). So, the collected samples were considered as *U. vittatus* based on BODYDD. The same technique was applied for all the morphometric characteristics.

DNA extraction, amplification of the mitochondrial cytochrome oxidase 1 (CO1) gene and sequence analysis

A standard phenol/chloroform extraction protocol was followed for DNA extraction. A 650 bp region of the mitochondrial CO1 gene was amplified using universal primers (Folmer *et al*., 1994). PCR reaction mixture consisted of 10mM Tris-HCl, 50 mM KCl, 1.5 mM $MgCl_2$, 200 µM each of dNTPs, 0.2 µM each of the forward and reverse primers, 1 unit of Taq DNA polymerase and 50 ng of template DNA. The amplifications were carried out in Biorad T100 thermocycler (Biorad, USA) under the PCR conditions: Initial denaturation at 94^0C for 4 min, followed by 33 cycles of - denaturation at 94^0C for 30 s, annealing at 42^0C for 30 s, extension at 72^0C for 40 s and a final extension at 72^0C for 7 min.

The PCR products were purified using Qiagen PCR purification kit and subsequent sequencing was carried out with the forward and reverse primers (LCO1490 and HC02198; Folmer *et al*., 1994) using the BigDye Terminator Sequencing Ready Reaction v3.0 kit (Applied Biosystems). The sequence generated was identified up to species level by comparing with sequences deposited in NCBI GenBank.

Results and discussion

External features

Based on the presence of dark first dorsal fin tip in all the collected samples, they were identified as *'vittatus'* group goatfishes. Retention of dark first dorsal fin tip and disappearance of lateral body stripes in formalin preserved fishes reconfirmed that all the collected fishes belonged to '*vittatus'* group.

The only external characteristic in the collected specimens that exclusively coincided with *U. supravittatus* was the two narrow, pale brown lateral body stripes, as described by Uiblein and Heemstra (2010) (Fig. 1). The caudal bar characteristics (size, shape and number) matched with *U. supravittatus* as well as *U. suahelicus.* The shorter lower caudal fin lobe and wide distal-most oblique bar in some of the adult specimens overlapped with the traits of *U. vittatus* (Fig. 2a,b).

According to Uiblein and Heemstra (2010), *U. taeniopterus* does not possess a dark first dorsal fin tip. Based on the examination of external features, presence of *U. taeniopterus* among the collected samples was ruled out.

Fig. 1. *U. supravittatus* from Chennai coast, south India

(a) (b)

Fig. 2. Caudal fin of (a) young and (b) adult *U. supravittatus*

Morphometric measurements

Morphometric measurements for 15 characteristics were taken from the collected fish samples (n=100) and the values were compared with the corresponding values recorded for *U. taeniopterus, U. indicus, U. vittatus, U. suahelicus* and *U. supravittatus* recorded by Uiblein and Heemstra (2010) (Table 1). Based on the HFO of morphometric values, the collected fishes resembled *U. vittatus* in BODYDD, BODYDA, HEAD1, PECTL and D2H characteristics, *U. supravittatus* in HEAD2, ORBITL, CAUL, ANALH, PELVL characteristics, *U. suahelicus* in HEADL and D1H characteristics, *U. taeniopterus* in CPDD, UJAWL and BARBL characteristics, while none of the characteristics resembled *U. indicus*.

The cumulative total of the HFO of the morphometric values were 718 and 684 for *U. vittatus* and *U. supravittatus,* respectively. Based on the morphometric values, it was concluded that the collected specimens had the morphometric characteristics of *U. vittatus* (718) as well as *U. supravittatus* (684).

Table 1. Morphometric characteristics of *U. supravittatus* (n=100) collected along Chennai coast compared with values (%SL) of *U. taeniopterus, U. indicus, U. vittatus U. suahelicus* and *U. supravittatus* recorded by Uiblein and Heemstra (2010). The highest frequency of overlapping (HFO) of the morphometric values is mentioned within brackets in the relevant species column

Morphometric characteristics	Measurement by Uiblein and Heemstra (2010)					The range of values obtained for the collected the samples (n=100) in the present study
	U. taeniopterus	*U. indicus*	*U. vittatus*	*U. suahelicus*	*U. supravittatus*	
Body depth at first dorsal fin origin (BODYDD)	22-25 (17)	29-31 (1)	25-29 (65)	26-30 (49)	26-30 (49)	22.5- 28.4 HFO to *U. vittatus*
Body depth at anal fin origin (BODYDA)	20-23 (47)	26-27 (0)	21-24 (73)	22-26 (57)	22-25 (56)	20.0-25.4 HFO to *U. vittatus*
Caudal peduncle depth (CPD)	9.7-11 (13)	11 (0)	9.9-12 (7)	9.9-11 (7)	9.9-11 (7)	8.1-13.5 HFO to *U. taeniopterus*
Maximum head depth (HEAD1)	17-21 (3)	25 (1)	21-26 (75)	22-25 (62)	23-26 (58)	20.1-32.7 HFO to *U. vittatus*
Head depth across a vertical midline through eye (HEAD2)	14-17 (12)	18-19 (21)	18-20 (44)	17-19 (45)	17-20 (67)	15.3-20.9 HFO to *U. supravittatus*
Distance between snout tip to posterior most margin of the operculum (HEADL)	25-29 (5)	30-31 (30)	30-31 (30)	28-31 (58)	30-33 (52)	27.7-32.6 HFO to *U. suahelicus*
Horizontal fleshy orbit diameter (ORBITL)	4.4-6.3 (0)	7.0-7.1 (12)	7.0-8.7 (63)	7.1-9.4 (61)	6.8-8.5 (77)	6.4-8.9 HFO to *U. supravittatus*
Distance between symphysis and posterior end of upper jaw (UJAWL)	11-13 (51)	12 (0)	11-13 (50)	12-14 (11)	12-14 (11)	7.8-12.5 HFO to *U. taeniopterus*
Barbel length (BARBL)	17-21 (67)	19-20 (30)	17-21 (66)	15-20 (63)	19-23 (36)	16.4-25.0 HFO to *U. taeniopterus*
Caudal fin length (CAUL)	28-32 (61)	27-28 (9)	26-30 (59)	26-30 (59)	27-31 (65)	23.3-32.7 HFO to *U. supravittatus*
Distance between anal-fin origin and anal-fin anterior tip (ANALH)	15-17 (48)	13-14 (9)	15-16 (31)	15-17 (48)	14-17 (73)	12.3-17.4 HFO to *U. supravittatus*
Distance between pelvic-fin origin and pelvic-fin tip (PELVL)	18-20 (28)	19 (2)	18-21 (28)	18-21 (28)	18-21 (28)	14.4-19.3 HFO to *U. supravittatus*
Distance between pectoral-fin dorsal origin and pectoral-fin tip (PECTL)	17-20 (0)	23-24 (28)	22-24 (35)	25-26 (15)	25-28 (19)	21.9-27.8 HFO to *U. vittatus*
Distance between first dorsal-fin origin and first dorsal-fin anterior tip (D1H)	20-23 (51)	23-24 (39)	22-23 (26)	22-26 (54)	23-26 (30)	19.2-25.2 HFO to *U. suahelicus*
Distance between second dorsal-fin origin and second dorsal-fin anterior tip (D2H)	14-16 (66)	15-16 (46)	14-16 (66)	16-18 (13)	15-17 (56)	13.9-17.2 HFO to *U. vittatus*
Cumulative total	469	228	718	630	684	

Meristic counts

Thirteen meristic characteristics were counted for the collected fish samples (n=100) and compared with the corresponding values reported for *U. taeniopterus, U. indicus, U. vittatus U. suahelicus* and *U. supravittatus* (Table 2). The dorsal spine count (8), lateral line scale count (36-37), bars on upper caudal fin (4-5), bars on lower caudal fin (3-4) and total caudal bar count (7-9) of the collected fish samples overlapped with all the five species of '*vittatus'* group. But the pectoral fin ray count (16-17) strictly coincided with *U. supravittatus* (Table 2).

Gill rakers play a major role in species identification of goatfishes (Uiblein and Heemstra, 2010). In the present study, the total number of gill rakers in collected fishes was constantly 29, with 8 rakers on the upper limb and 21 rakers on the lower limb. A unique feature was noticed on the upper limb gill rakers of all the fishes wherein, out of the 8 gill rakers of the upper limb, the developed gill rakers were always either 3 or 5 and if the developed rakers were 3, the rudimentary rakers were 5, whereas if the developed rakers were 5, the rudimentary rakers were 3. Similarly on the lower limb, the developed gill rakers were either 16 or 17 and rudimentary rakers were between 4 and 5 (Fig. 3). The number of rudimentary gill rakers (3 to 5) on the upper limb of the first gill arch of all the collected goatfishes confirmed the samples to be *U. supravittatus.*

U. supravittatus is a small-sized goatfish. The common standard length (SL) recorded is 14 cm (Uiblein and Heemstra, 2010) and maximum SL is 18.7 cm (Uiblein and Gouws, 2015). The fishes collected (n=100) for the

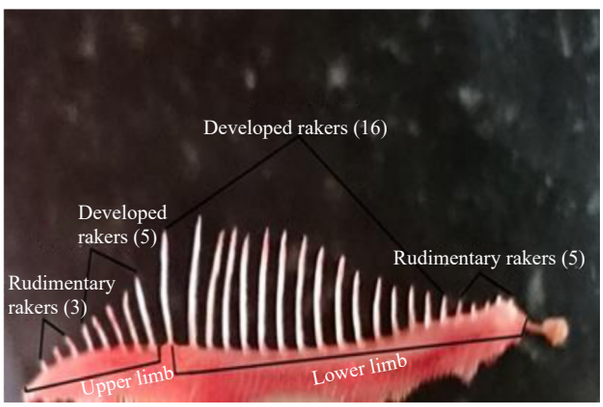

Fig. 3. First gill arch with gill raker arrangement in *U. supravittatus*

Table 2. Meristic characteristics of goatfish (n=100) collected along Chennai coast compared with *U. taeniopterus, U. indicus, U. vittatus U. suahelicus* and *U. supravittatus* recorded by Uiblein and Heemstra (2010)

Meristic characteristics	Meristic counts by Uiblein and Heemstra (2010)					Present study
	U. taeniopterus	*U. indicus*	*U. vittatus*	*U. suahelicus*	*U. supravittatus*	(n=100)
Dorsal fin spine (DF)	8	8	8	8	8	8
Pectoral fin rays (PF)	13-14	15-16	15-16	15-16	16-17	16-17
Developed gill rakers on the upper limb (GrUd)	2-3	6-8	4-7	5-7	3-8	3-5
Rudimentary gill rakers on the upper limb (GrUud)	2-4	1-3	1-4	0-2	0-5	3-5
Total gill rakers on the upper limb (GrU)	5-6	7-9	7-8	6-8	7-9	8
Developed gill rakers on the lower limb (GrLd)	10-13	16-17	13-17	15-19	16-21	16-17
Rudimentary gill rakers on the lower limb (GrLud)	3-6	3-5	4-6	1-5	2-5	4-5
Total gill rakers on the lower limb (GrL)	16-17	20-22	19-21	19-21	21-23	21
Total gill rakers on the 1st gill arch (Gr)	21-23	29-31	27-29	26-28	29-32	29
Lateral line scale count (LLscal)	35-39	36	36-38	34-35	34-36	36-37
Bars on upper caudal fin (BarU)	4-8	4-6	4-5	4-6	4-6	4-5
Bars on lower caudal fin (BarL)	3-6	4	3-4	3-4	3-5	3-4
Total caudal bars (TBar)	7-13	8-10	7-9	8-10	8-10	7-9

present study were within the range of 9.3-15.4 cm with maximum SL of 15.4 cm. The maximum size recorded at Chennai was 16.2 cm SL (Gomathy, 2013). *U. vittatus* and *U. taeniopterus* are relatively large-sized goatfishes with maximum recorded SL of 28 and 27 cm respectively (Uiblein and Heemstra, 2010).

The paratype specimens of *U. supravittatus* recorded by Uiblein and Gouws (2015) from different parts of India are - South-west India, Kerala: USNM 267679, 5 specimens, 104-108 mm, PT, Vizhinjam, 8°22'N, 76°58′E; East India, Madras State: BPBM 20504, 3 specimens, 112-133 mm, PT, Madras, 40 m; MNHN A3463, 100 mm, Puducherry, 11°58′59″N, 79°49′59″E; and USNM 396114, 6 specimens, 127-144 mm, PT, Puducherry. Based on the area of distribution (Table 3), the chances of occurrence of *U. supravittatus* are more along Chennai coast, when compared to *U. taeniopterus* and *U. vittatus*.

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Table 3. Maximum size (standard length, cm) and area of distribution of *U. taeniopterus, U. indicus, U. vittatus U. suahelicus* and *U. supravittatus* recorded by Uiblein and Heemstra (2010)

Species	Maximum size (cm)	Distribution
U. taeniopterus of *"tragula"* group	27.0	Indo-pacific: East Africa to Hawaii; north to Japan, Ogas
U. indicus	14.0	Western Indian Ocean: Only western India
U. vittatus	28.0	Indo-pacific: Red Sea south to East London, South Africa and east to Micronesia and the Hawaiian, Marquesan and Society islands, north to southern Japan, South to New Caledonia
U. suahelicus	13.5	Western Indian Ocean: Kenya to South Africa, Eritrea (Red Sea)
U. supravittatus	14.0	Sri Lanka; southern India
	15.4	Chennai (Present study)
	16.2	Chennai (Gomathy, 2013)

Molecular analysis

Based on the mitochondrial CO1 gene sequence analysis, the species was confirmed as *Upeneus supravittatus* with 99% identity. The partial sequence of CO1 region was deposited in GenBank with the Accession No. OQ706230.

From the morpho-meristic analysis and DNA sequencing, it is concluded that the specimens collected at Chennai were *U. supravittatus*. It appears that *U. supravittatus* is a common species occurring along the Chennai coast and the same may be true for a major part of the Indian coast. However, even after the detailed species identification key published by Uiblein and Heemstra (2010), *U. supravittatus* has not been reported along the Indian coast. Considering this, a detailed study on the '*vittatus'* group along the Indian coast needs to be undertaken using morphometric and meristic characteristics and DNA barcoding.

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