Indian J. Fish., 60(2) : 49-58, 2013

Morphological characteristics of selected body parts of trigger fishes (Tetradontiformes, Balistidae) from India with details on ultrastructural features of body scales

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ABSTRACT

The morphological characters like shape of teeth, nasal apertures, gill rakers and scales of trigger fishes collected from southern India were studied during the period 2000-2002. Based on the shape of the first and second teeth of the upper and lower jaw, five types have been identified. The anterior nasal aperture has different shapes, which is species specific but the posterior aperture is similar in all species. Based on the shape of the anterior nasal aperture, five types have been identified. The outermost branchial arch possesses gill rakers and based on shape they are divided into five types. Scales on body and caudal peduncle are diamond shaped, whereas scales on cheek are rhomboid, rectangular, square or triangular occurring in different combinations. The arrangement of scales on body, abdomen and caudal peduncle were similar in all the species studied while scales are arranged in three patterns on cheek. Scales on cheek are of seven types based on shape of the scale and type of protuberances it possessed on the posterior margin. Body scales are of five types and scales on abdomen are of three types. Transverse section of body scales under the scanning electron microscope (SEM) revealed that the scales consist of four layers. Studies on the ultrastructure of the anterior margin of the body scales revealed that there are five types; based on the type of protuberances it possesses and there are of four types of posterior margin.

Keywords: Caudal peduncle, Morphology, Nasal apertures, Scales, SEM, Teeth, Trigger fishes

Introduction

A character is a trait of any organism that can be detected and described. The knowledge of how a set of characters varies among species and other taxa allows the identification of the organism. From a practical point of view, it is essential to find easily observable morphological characters for use in identifying species and other taxa. Trigger fishes (Family: Balistidae) are known from fossil records of Eocene and Oligocene period and recently several new genera and species of the earlier members were described (Bannikov and Tyler, 2008). Evolutionary importance of the trigger fishes are more evident now due to several excavations in Italy which resulted in the comparison of morphology and appearance of the modern and fossil species. External morphological characters have been the key source for species identification. Some of the characters like body shape, colour, snout shape, groove position before eye, shape of the mouth and its position, type of teeth, fins (number of rays, spines, position of the fin on the body), caudal peduncle shape, presence or absence of spines on it *etc*. were recognised by earlier workers (Lacepede, 1798; Swainson, 1839; Bleeker, 1866; Day, 1878; Weber and Beaufort, 1962; Matsuura,1976; 1980; 1981; 2001; Smith and Heemstra, 1986), considering their potential in identifying the species. These characters were put in different combinations for preparing keys for identifying the genera and species. Some of these characters were described using ambiguous terminologies making it very difficult to identify a species.

The importance of scales for the classification and identification of fishes including trigger fishes have been observed by several workers (Swainson, 1839; Bleeker; 1869; Norman, 1934; Lagler, 1952; Weber and De Beaufort, 1962; Matsuura, 1980; Smith and Heemstra, 1986; Bridge and Boulenger, 1989). The present work deals with external morphological characters of trigger fishes from Indian seas to reveal the diversity of shapes and patterns present in this group. It is the first attempt to study the external morphological characteristics of triggerfishes based on the shapes of the fins, shapes and structure of teeth, position, shapes and structures of nasal apertures, shape and structure of scales using scanning electron microscope (SEM) and pattern as well as arrangement of scales in different regions of the body

Material and methods

Samples of triggerfishes were collected from hook and lines as well as trawl landings at Tuticorin, Kanyakumari, Chennai, Mandapam and Keelakarai along the south-east coast and Vizhinjam, Colachel, Mumbai and Veraval along the south-west coast of India and from Minicoy Islands in Lakshadweep, during August 2000 to October 2002. Descriptions of shape of the teeth and fins were made after proper spreading of the mouth and fins. The shape of the nasal apertures and gill rakers were studied under a stereozoom microscope. The scales on cheek, body, abdomen and caudal peduncle were selected and examined under stereozoom microscope (magnification 5x – 20x) to compare the arrangement, shape and morphology (Fig. 1 A and B). After the initial study, scales with skin were dissected out and boiled in 5% KOH solution for 5 min to separate the scales from tissue, in order to observe the shape and arrangement of protuberances. The scales were first examined under a stereozoom microscope and later treated in 1% osmium tetroxide and coated with gold in a gold sputter coater for observation under scanning electron microscope (Hitachi H600 Electron Microscope having an H6010-A SEM attachment with magnification of 100x and 200x).

Certain terms used for the description of scales are the following:

- Anterior margin: embedded part, anterior margin of the scale (Fig. 2 A).
- Posterior margin: exposed part, posterior margin of scale when scale is intact on fish (Fig. 2A).
- Protuberances: a projection on the scale surface which is ridge-like (Fig. 2B), round (Fig. 2C), spiny antrose or retrose (Fig. 2. D and E).

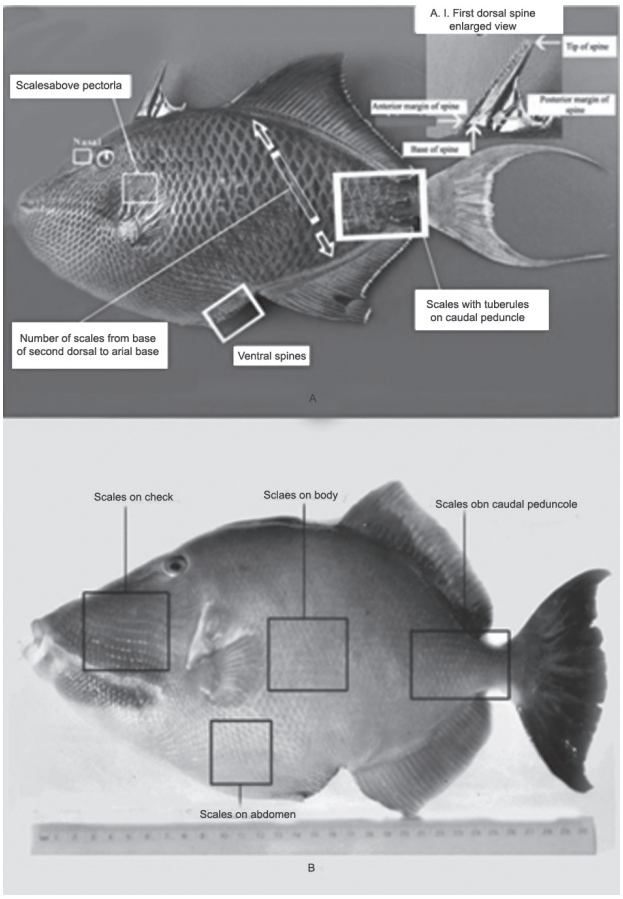

Fig. 1. A & B. The meristic and morphological characters, position of scales on cheek, body, abdomen and caudal peduncle of trigger fish

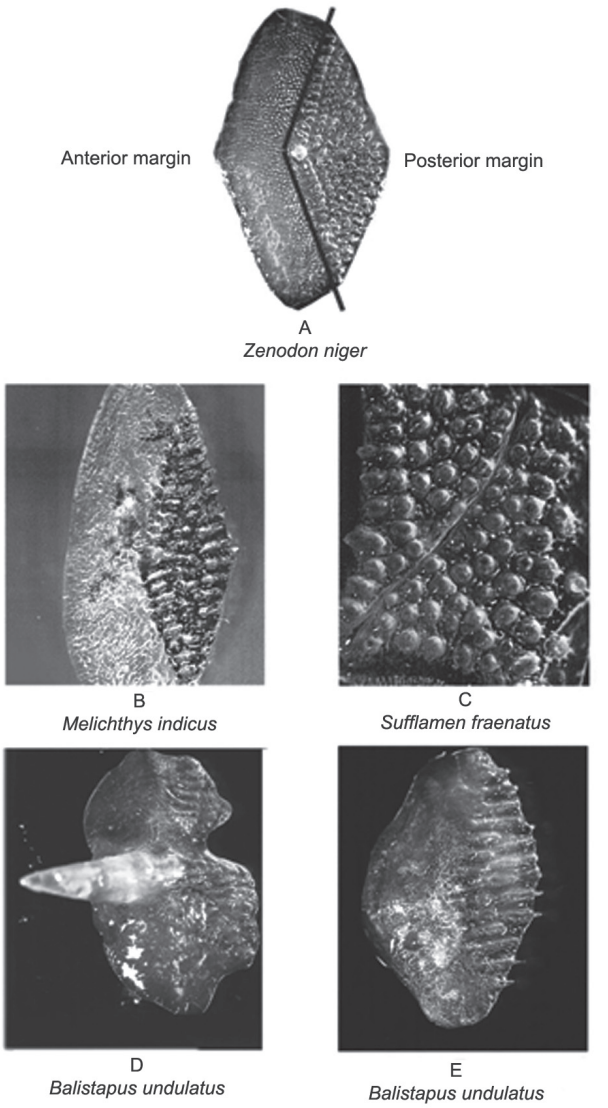

Fig. 2. A-. The anterior and posterior margin of the scale, B - Ridge-like protuberances, C - Round protuberances, D - Antrose spines, E - Retrose spines

Results

Body shape

The trigger fishes have a laterally compressed body. Most of the species have rhomboid or an oval shaped body, whereas some have an oval-elongate body.

Second dorsal and anal fin

The second dorsal and the anal fins (unpaired fins) display symmetry and the shapes are species specific. These fins can be divided into two types based on the height : 1) fins with height less than half the depth of the body: 2) fins with height more than half the depth of the body. Fins belonging to the first category are mostly rectangular, transparent, thick at base and thin at the top with different types of outer borders which range from straight (Fig. 3 A), convex (Fig. 3 B), elevated at the anterior (Fig. 3 C) and wavy edged (Fig. 3 D). The rays in these fins are almost of the same length except in some cases where the anterior rays are the longest, compared to the other rays "elevated at the anterior". In case of "convex" fins, the middle rays are the longest. The fins belonging to the second type have a concave upper border (Fig. 3 E) with the base being thick and upper margin thin, in some case wavy; the anterior longest ray gives the appearance of a separate lobe, posterior most rays being less than half the length of the first ray.

Teeth

Trigger fishes have two types of teeth, arranged in two separate rows on the upper jaw. The inner row consistss of three teeth, which are pear shaped to rectangular having thin and sharp edge, placed in the interdental gap of the outer teeth. The outer row has four teeth; with the first teeth flat projecting outside. Lower jaw has a single row of four teeth.

Based on the shape of the first and second teeth of the upper and lower jaws, five categories have been identified *viz*., 1) the first and the second teeth conical (dagger shaped), with tips pointed and directed inward (Fig. 4 A); 2) first and the second teeth rectangular with tips convex towards the inside (Fig. 4 B); 3) first teeth of the upper jaw rectangular, but teeth of lower jaw rectangular with a concave tip, the second teeth caniniform and orange coloured (Fig. 4 C); 4) first teeth of upper jaw conical with

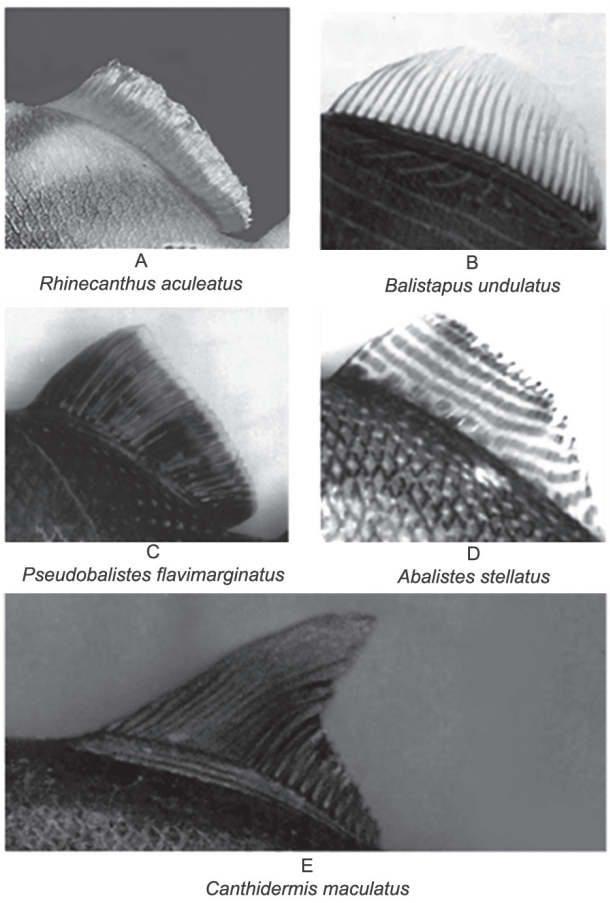

Fig. 3. Types of second dorsal fin of trigger fish

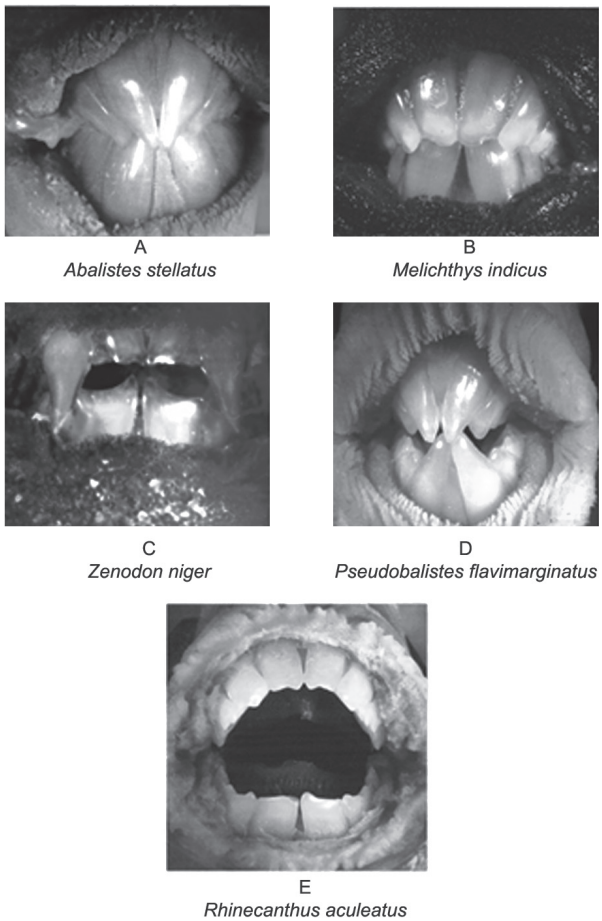

Fig. 4. Pattern of teeth arrangement in trigger fishes

pointed tip diverging outside; the first teeth of the lower jaw also conical with the tip diverging towards the inside, rest of the teeth of both jaws with a rectangular base and a conical projection, towards the anterior (Fig. 4 D); 5) all the teeth of upper jaw rectangular with serrated edge (Fig. 4 E). Teeth of the lower jaw are symmetrical to upper jaw, but directed inwards

Nasal aperture

The nasal apertures – anterior and posterior, are situated in small depression along the anterior border of the eye. The anterior nasal aperture has different shapes, which is species specific but the posterior aperture is similar in all species. Based on the shape of the anterior nasal aperture five categories have been identified: 1) funnel shaped with edges decurved and a lobe towards the posterior (Fig. 5 A); 2) dome shaped with a pore at the tip (Fig. 5 B); 3) tube like with an irregular edge (in some it is a short tube), which is directed forward (Fig. 5 C); 4) the anterior nasal aperture with a circular flap over the circular opening (Fig. 5 D); 5) dome shaped with a circular opening guarded by a fleshy cone from inside (Fig. 5 E).

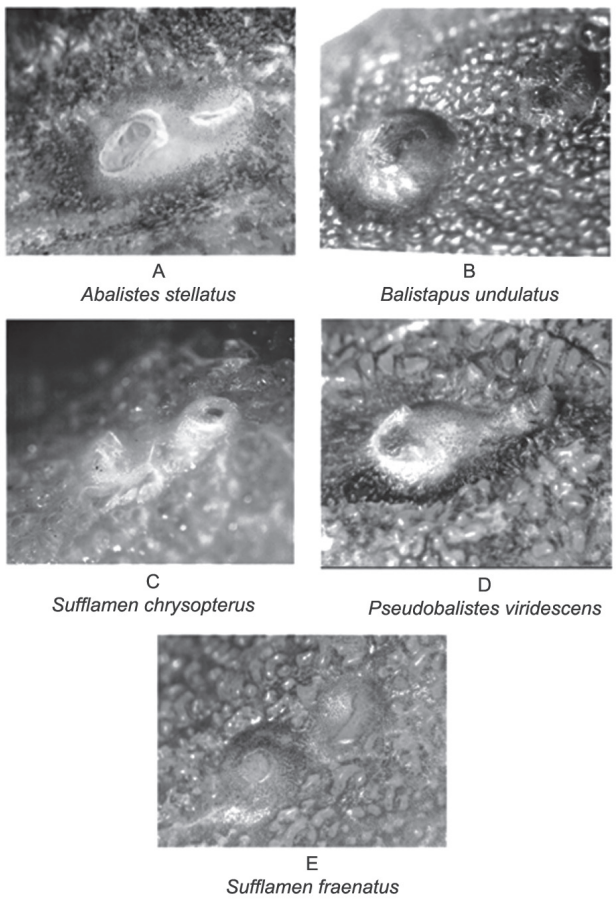

Fig. 5. Types of nasal apertures of trigger fishes

Gills

Trigger fishes have four pairs of gills, supported on C-shaped branchial arch. The outer most branchial arch possesses gill rakers. Based on the shape they are divided into five types : 1) slender, hyaline pointed and elongated (Fig. 6 A); 2) short and conical with pointed tip (Fig. 6.B); 3) blunt with globular protuberances towards inside (Fig. 6 C); 4) pointed with bristles towards the inside (Fig. 6 D); 5) blunt tipped, hyaline, serrated towards the inside (Fig. 6 E).

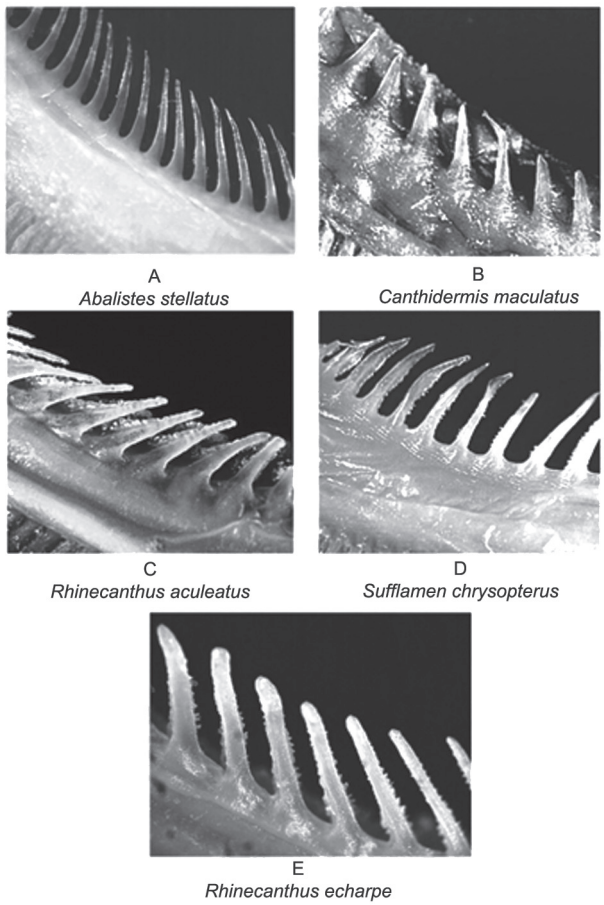

Fig. 6. Gill raker types in trigger fishes

Scales

a) Morphology and arrangement

Scales on body and caudal peduncle are diamond-shaped whereas scales on the cheek and abdomen are rhomboid, rectangular, square or round shaped with round edges. These scales have a dorsal exposed part called posterior margin and a ventral basal plate called anterior margin (Fig. 4 A). The anterior margin forms anterior part of the basal plate, which is embedded in the dermis. Based on the position of the scale on the body, the width of the anterior margin varies. It is widest in the scales found on

the body and narrowest in the scales on cheek. The posterior margin consists of horizontal or vertical rows of ridges, round protuberances, antrose or retrose spines. Arrangement and type are species specific. At the centre of the posterior margin is present the central canal (minute pore). The morphology and arrangement of scales on cheek, body, abdomen and caudal peduncle are described below:

i) Cheek scales

These scales have "<" shaped anterior margin. The posterior margin is elevated from the anterior margin. The width of the anterior margin is equal to the posterior margin in most of the cases, wherever there is a change, it is mentioned. Cheek scales are of seven types:

Type I: Scales are rhomboid, diamond or rectangular shaped. The anterior margins are "<" or "L" shaped, thin and smooth. The width of the anterior margin is half of the posterior margin. The posterior margin is rhomboid and consists of 3-8 vertical rows of round protuberances (Fig. 7 A).

Type II: Scales are diamond shaped and anterior margin is "<"shaped, thin and have horizontal ridges. The posterior margin is diamond shaped and consists of 3-5 vertical rows of horizontal ridges (Fig. 7 B).

Type III: Scales are round, square, diamond or rectangular shaped. The anterior margin is "<", "[" or "C" shaped, thin at the anterior most edges and thick posteriorly. Width of the anterior margin is twice that of the posterior margin. The posterior margin is square, rhomboid or round having round protuberances and transverse ridges, which are arranged in 3 - 5 vertical rows. In round scales, the posterior margin is not very clearly demarcated (Fig. 7 C).

Type IV: Scales are pentagonal, hexagonal or round in shape and anterior margin is thin "<" or "(" shaped. The posterior margin is rhomboid with "<" or "l" shaped 5-8 vertical rows having horizontal ridges at the anterior first row and round protuberances as well as ridges in subsequent posterior rows (Fig. 7 D).

Type V: Scales are diamond or rhomboid shaped, antero-posteriorly compressed and dorso-ventrally elongated. The anterior margin is thin having horizontal ridges. The width of the anterior margin is half that of the posterior margin. The posterior margin is rhomboid having 3-5 vertical rows of small to large round protuberances (Fig. 7 E).

Type VI: Some of the scales are rectangular or rhomboid; few are antero-posteriorly compressed and dorso-ventrally elongated, have a smooth surface and covered with a thin skin when intact on the fishes, especially occupying fleshy groove. The anterior margin is thin. The width of the anterior margin is one-fourth that of the posterior margin. The posterior margin is rhomboid having 1- 4 vertical rows of small round protuberances and ridges; some scales have a smooth surface with shallow depressions and ridges (Fig. 7 F).

Type VII: Scales are diamond, rhomboid, round or triangular and anterior margin is thin with few ridges. The width of the anterior margin is half that of the posterior margin in some and in others it is one-fourth that of the posterior margin. The posterior margin is rectangular, square or rhomboid having 3-8 vertical rows of round protuberances arranged in "<" or "l" shaped vertical rows. (Fig. 7 G).

There are three types of arrangement of scales on cheek:

Type I: The rhomboid scales are arranged in vertical rows, anteriorly and obliquely at the posterior (Fig. 8 A).

Type II: The rhomboid to square scales are arranged in horizontal rows. The type of scales in the row varies: a) scales square at the anterior and rhomboid to rectangular posteriorly; b) scales square at the anterior, with some triangular scales in between and rhomboid scales posteriorly; c) scales completely rectangular (Fig. 8 B).

Type III: The square and rhomboid scales are arranged in horizontal rows with wide transverse fleshy horizontal grooves (the horizontal grooves also possess rectangular, rhomboid and elongated scales which is completely covered by a thick skin). In this arrangement there are three types : a) scales at the anterior irregular shaped, posteriorly rhomboid with horizontal grooves; b) scales at the anterior covered by skin, posteriorly 3-5 horizontal rows of square and rectangular scales; in between the posterior rows are present horizontal grooves; c) scales covered by skin anteriorly, posteriorly horizontal rows of square scales are present with wide horizontal fleshy grooves (Fig. 8 C).

ii) Body scales

In body scales, the width of the anterior margin is equal to that of the posterior margin. The anterior margin is "<" shaped. The posterior margin is diamond shaped. Body scales are of five types:

Type I: The anterior margin is thin and smooth. Posterior margin is slightly elevated from the anterior margin and has ridges on the first row with a large round protuberance at the middle of the scale. Round protuberances are arranged in 2-7 vertical rows (Fig. 7 H).

Type II: Anterior margin is thick, posterior margin has 5 - 10 vertical rows of round protuberances; the anterior most rows of round protuberances are small followed by larger protuberances (Fig. 7 I).

Type III: Scales are diamond or rectangular shaped with round edges. The anterior margin is thick. The posterior margin has 5-10 vertical rows of ridges tapering towards

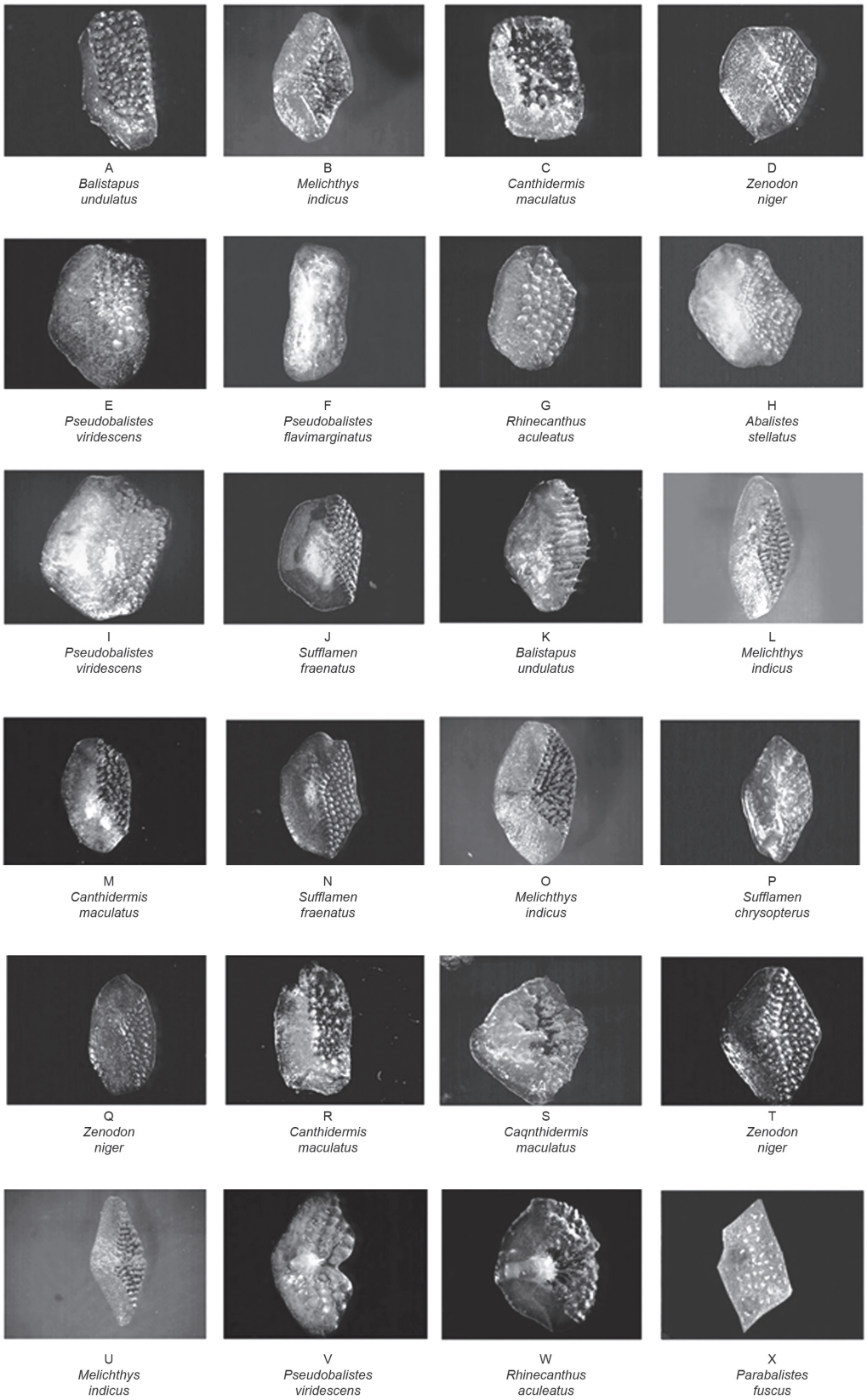

Fig. 7. Pattern of protuberances on scales in the cheek, body, abdomen and caudal peduncle of trigger fishes

the posterior; the anterior most rows of ridges are large (Fig. 7 J).

Type IV: Anterior margin is thick and posterior margin has 3-5 vertical rows of retrose spines (Fig. 7 K).

Type V: The anterior margin is thin and the posterior margin has 3-5 vertical rows of ridges (horizontally placed) (Fig. 7 L).The scales are arranged in oblique rows. The scales on the body are rhomboid (Fig. 8 D).

iii) Abdominal scales

The scales on the abdomen are diamond or rhomboid shaped, with round edges. The anterior margins are "<" shaped, thin anteriorly with smooth surface. The width of anterior margin is equal to that of the posterior margin. The posterior margin is diamond shaped. They are of three types:

Type I: The posterior margin is rhomboid having 3-4 oblique rows of protuberances. The protuberances are either horizontal ridges or ridges which taper towards the posterior or ridges which taper towards the anterior or round protuberances. In some, the posterior margin has horizontal ridges on the first row, followed by 3-5 rows of round protuberances (Fig. 7 M).

Type II: The posterior margin is rhomboid having a round posterior edge. These scales have horizontal ridges on the first row followed by 3-5 oblique rows of round protuberances (Fig. 7.N and O).

Type III: The posterior margin is rectangular or square shaped, having 3-5 oblique rows of round protuberances. At the anterio-ventral corner is present a round protuberance slightly larger than the other protuberances (Fig. 7 P-R). The scales are arranged in oblique rows. There are two types of scales on the abdomen - rhomboid and rectangular (Fig. 8 E).

iv) Caudal peduncle scales

Scales are diamond shaped, with round edges and posterior margin slightly elevated from the anterior margin. The anterior margin is smooth, "<" shaped, thin anteriorly and thick posteriorly. Width of the anterior margin is equal to the width of the posterior margin. The posterior margin is diamond shaped. These scales are of five types:

Type I: Posterior margin has 3-4 rows of horizontal ridges at the middle and 3 -5 horizontal rows of round protuberance on both sides of the ridges (Fig. 7 S).

Type II: The posterior margin has 5-10 vertical rows of round protuberances; the anterior most rows have a large round protuberance at the middle (Fig. 7 T).

Type III: Posterior margin has 10-20 horizontal rows of ridges with 3- 4 ridges at the centre slightly elevated and to the anterior of these ridges is present a pointed round protuberance (Fig. 7 U).

Type IV: The posterior margin has 3-5 vertical rows of round protuberances with the anterior most rows having a ridge at the centre, which tapers towards anterior (Fig. 7 V).

Type V: The posterior margin has 3-5 vertical rows of horizontal ridges tapering towards the posterior and an antrose spine at the middle, whereas in others there are 5-8 horizontal rows of ridges tapering towards posterior (Fig. 7 W).

Type VI: The posterior margin has 3-5 vertical rows of round protuberances. (Fig. 7 X). The diamond-shaped scales are arranged in transverse rows (Fig. 8 F).

b) Ultrastructure of scales

Transverse sections of the body scales under the SEM revealed that the scale consists of four layers; the upper most layer is glassy, just below is a perforated layer,

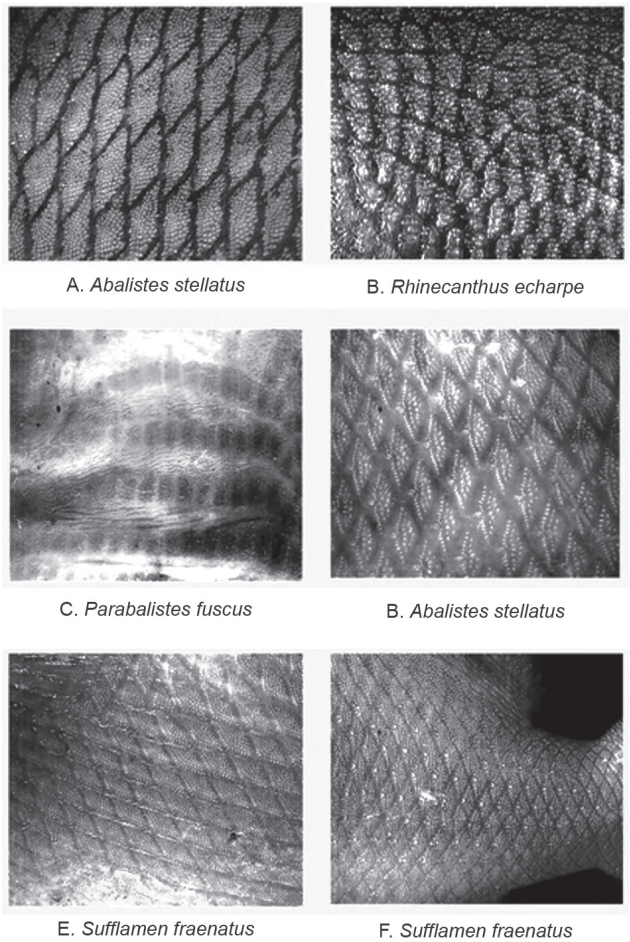

Fig. 8. Arrangement of scales on cheek, body, abdomen and caudal peduncle in trigger fishes

followed by a vascular area consisting of transverse and longitudinal canals and the fourth layer is thickest and opaque. These four layers are well demarcated at the anterior and middle portions of the posterior margin, but the posterior portion of the posterior margin is highly compressed and the layers are not well demarcated (Fig. 9 A-F). The gross morphology is very similar to that of the ganoid scale (Sire, 1989). Since peg like extensions are not found in these scales, (which is the character of the ganoid scales) these scales cannot be classified as ganoid. Hence they are classified as palaeoniscoid scales, which are also found in fishes of the family Polypteridae (Bond, 1979). The anterior and posterior margins are characteristically different between species.

i) Anterior margin

The anterior margin of the scales is of five types, based on the type of protuberances it possess, (ridges, pits, and network of fibres).

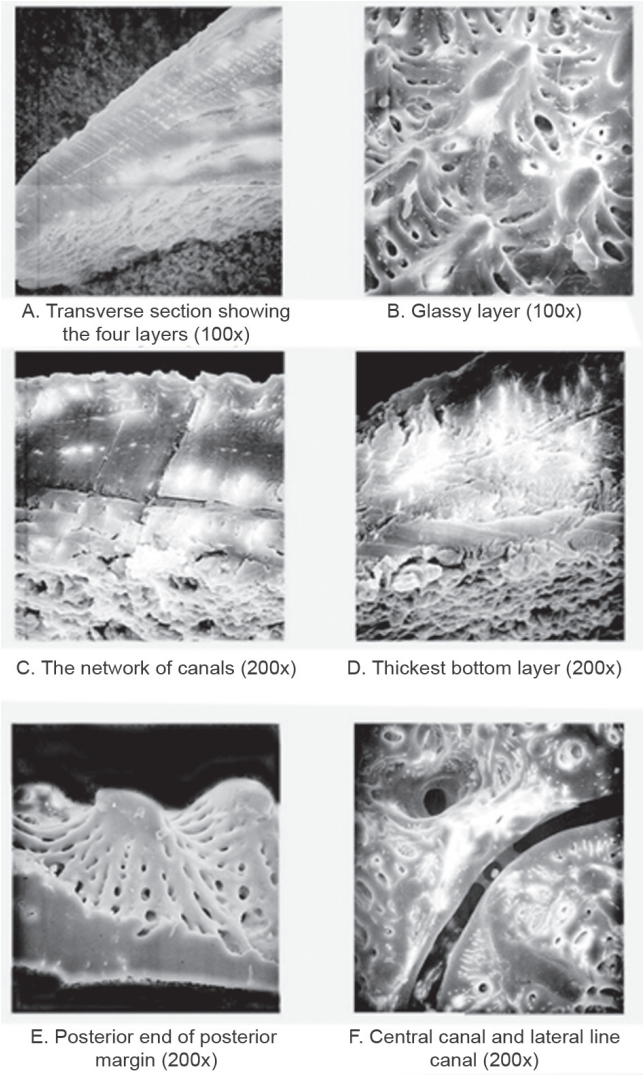

Fig. 9. Ultrastructure (SEM) of body scales of *Abalistes stellatus*

Type I (Ridges): The anterior margin has horizontal ridges, which are arranged in many semicircular rows (Fig. 10 A).

Type II (Pits): The anterior margin has many pits arranged in transverse rows. All the pits have many pores (Fig. 10 B).

Type III (Ridges and circular protuberances): The anterior portion has many round protuberances, with ridges in between. The arrangement varies in some species with horizontal ridges at the anterior part arranged in different layers (placed one above the other) and round protuberances and pits posteriorly (Fig. 10 C).

Type IV (Fibre and pits): The anterior margin has a network of thin fibres. Between these fibres are present many minute pits (Fig.10 D). In some, the fibrous network is made up of broad fibres with very few pits, circular and shallow. In others the fibrous network is marginal but the pits are large and almost circular.

Type V (Round, triangular, ridge like protuberances, grooves and pits): The anterior margin consists of horizontal ridges and round, triangular protuberances (Fig. 10 E). In some, the ridges are arranged in semicircular rows and between rows are present shallow grooves.

ii) Posterior margin

The posterior margin is also of four different types. The protuberances of the posterior margin include horizontal ridges, ridges tapering towards the posterior, retrose spine, round and conical. These protuberances are arranged on the perforated layer.

Type I (Horizontal ridges and pointed conical protuberance): The posterior margin has horizontal ridges and conical pointed protuberances. The horizontal ridges occupy the anterior row (Fig.10 F).

Type II (Horizontal ridges and retrose spines protuberance): The posterior margin has horizontal ridges and retrose spines; the former occupies the first row (Fig. 10 G).

Type III (Horizontal ridges like protuberance): Ridge like protuberances are arranged on few vertical rows (Fig. 10 H)

Type IV (Round protuberance): Round protuberances are arranged in 3-5 vertical rows (Fig. 10 I)

Discussion

The results obtained in the present study agree with some of the past studies on the body shape, colour, scales, teeth and fins of trigger fishes (Lacepede, 1798; Swainson, 1839; Bleeker, 1866; Day, 1889; Weber and Beaufort, 1962; Matsuura, 1981; Smith and Heemstra, 1986). The results of the present morphological and ultrastructural studies are

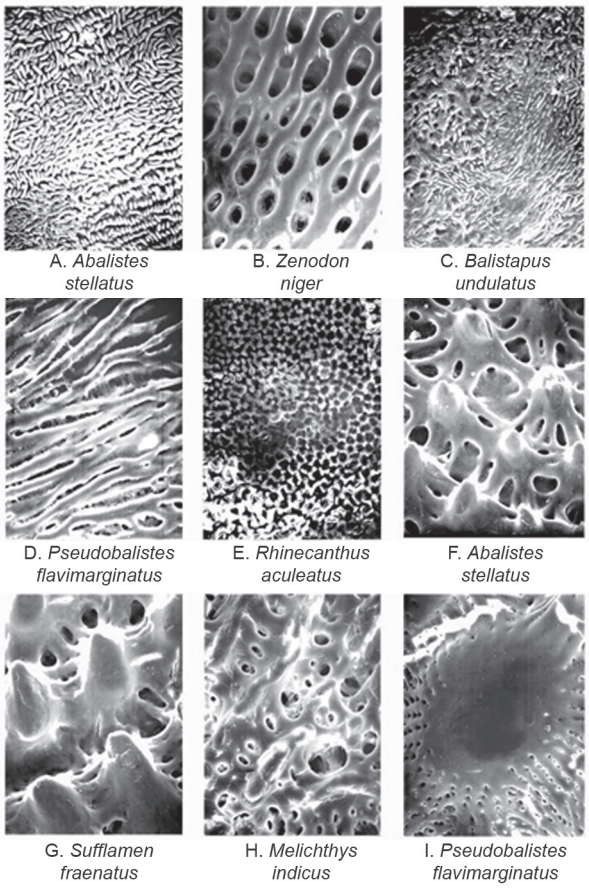

Fig. 10. Ultrastructure (SEM) of the body scale of trigger fishes,
A - E : anterior region,
F - I : posterior region

advanced, compared to some of the earlier studies (Day, 1889; Weber and Beaufort, 1962; Berry, 1966; Matsuura, 1980; 2001: Smith and Heemstra, 1986; Randall, 1995) and can aid easy and fast identification of species. Bridge and Boulenger (1989) described the scales of Sclerodermi as an intermediate between ordinary teleostean scales and dermal denticles. The scale has a rhombic basal plate, on which one or more spines are found, which may be simple or branched. Many workers described the scales in trigger fishes as covered with a granulated coriaceous skin, which is (typically) reticulated (Swainson, 1839), "*scutisrhomboideis*" (Bleeker, 1869), body covered with more or less imbricate osseous scales (Weber and De Beaufort, 1962), covered with strong rough, plate-like scales in regular series (Smith and Heemstra, 1986), covered with more or less imbricate plate-like scales, each scale with numerous small nodules and short longitudinal ridges (Matsuura,1980).

The present study reveals that cheek scales are of seven types and are arranged in three ways on cheek, Body scales are of five types and abdominal scales are of three types. The ultrastructure reveals that the scale consists of 4 layers - glassy upper layer, perforated layer, vascular layer and thicker opaque layer, all well demarcated at the anterior and middle portions and not well demarcated in posterior margin. The gross morphology is very similar to that of the ganoid scale (Sire, 1989). They are classified as palaeoniscoid scales as found in fishes of the family polypteridae (Bond, 1979). The present study revealed that the anterior margin of the scales are of five types based on the type of protuberances and posterior margin has four types. In the present study, detailed account of the morphology and ultrastructure of the scales have been brought out, which will be useful in species identification and further biological studies of these fishes. Structural details of the scales brought out in the present study using SEM is a pioneering attempt and can be considered as a potential technique for scale studies.

Acknowledgements

The authors are grateful to Director, CMFRI, Cochin and Dr. V. Sriramachandra Murty, former Head, Demersal Fisheries Division for the encouragement and facilities provided. The authors also wish to express gratitude to Dr. Rani Mary George, Head, Marine Biodiversity Division and SIC Vizhinjam, K. J. Abraham and N. Rudramurty. Authors acknowledge MLRE- MoES, Government of India, for financial support.

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Date of Receipt : 22.08.2012
Date of Acceptance : 14.02.2013