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THE VISUAL CELL MOSAICS IN THE RETINAS OF SOME SOUTH INDIAN MARINE TELEOSTS

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ABSTRACT

Studies on the structure of the retinas of the fishes is mostly based on their transverse sections. The present study employs tangential sections of the retinas for the proper understanding of visual cell layer and in particular the cone mosaics. In the ten species studied here two types of cone mosaic patterns are identified and are discussed in relation to their morphology as well as to the phylogeny and ecology of the species.

INTRODUCTION

THE RODS AND CONES are vertebrate photoreceptors which are present in the retina of the eye. Extensive studies on the histology and histophysiology of the fish retina indicate variation in the visual cells. Muller (1856) described single, double, short and large cones. Wunder (1925, 1926) determined the number of rods and cones in the eyes of various fishes. Muller (1952) and Lyall (1957 a) have also studied the cone mosaics in teleosts. Tamura (1957) concluded that the ratio of single cones to double cones has a tendency to be higher in shallow water fishes than in deep-water fishes. Lyall (1957 b) concluded that the double cones in teleosts species are associated with deep water adaptation.

Engstrom (1960) described the cone types and the arrangement of cones in some Cyprinids and Gadids. Engstrom (1963 a) studied the detailed structure of the visual cells in the teleost family Labridae and in flatfishes (Engstrom and Ahlbert, 1963). Engstrom and Rosstrop (1963) studied photomechanical responses in the different cone types in *Leuciscus rutilus*. Engstrom (1963 c) reviewed the ecology and phylogeny of teleostean visual cells. Munk's (1968) phylogenetic studies based on the eyes of *Amia* and *Lepideosteus* showed that the Holostean and Brachiopterygian eyes are related.

Most recent work on the correlated study of the transverse sections of the retina and cone mosaics are those of Anctil and Ali (1970) on the retina of *Exocoetus volitans* and *Fodiator acutus* in which the calculated visual acuity of the retinal area is less than that measured. Wagner, Menezes and Ali (1976) found that the retinal structure in some Brazilian tide pool fishes (teleostei) may be grouped into three categories, *viz.* (1) visually dependent, (2) specialized for dim environments and (3) with poor visual acuity; similarly Menezes, Wagner and Ali (1981) studying the retinal adaptations in fishes from a flood plain environment in the central Amazon basin came to the conclusion that in the flood plains characterized by dim light and turbid water the retinal adaptations seem more closely related to the species position in the habitat (permanent and temporary) and to their habits than to the stage of development (age).

The preceding work is confined mostly to the Atlantic Ocean fishes and to those of the American continent and literally no work of the kind mentioned above has been done on Indian species. This work is a study of the morphology of various kinds of the visual cell mosaics in

ten marine teleosts of the Madras coast in relation to their habitat and phylogeny.

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Material

The following ten species of fishes belonging to five families were examined for their retinal structure.

Sardinella longiceps (Family Clupidae) (Surface)

Scomber microlepidotus (Family Scombridae) (50 metres depth)

Elacate nigra (Family Scombridae) (50 metres depth)

Caranx leptolepis (Family Carangidae) (Bottom dwellers)

Upeneoides vittatus (Family Mullidae) (Bottom dwellers)

Upeneoides flavolineatus (Family Mullidae) (Bottom dwellers)

Serranus fuscoguttatus (Family Percidae) (50 metres depth)

Synagris tolu (Family Percidae) (Bottom dwellers)

Diagramma pictum (Family Percidae) (Bottom dwellers).

Therapon theraps (Family Percidae) (Bottom dwellers)

Methods

It is quite difficult to distinguish between twin, double and single cones in transverse sections. The only reliable method to distinguish between these retinal elements has been found to be a combined study of tangential and transverse sections.

Eyes from fresh fish procured from the fish landing centre at Royapuram, Madras were immediately fixed in Bouin's fluid for 24 hours and were incised to remove the lens and vitreous humour. The retina of the eye were removed and cut into small 3 to 5 Sq. mm. bits. The tissues were embedded in paraffin and sections 1 micron thick were taken using a rotary microtome. Sections were stained with Harris Haematoxylin and counter stained with alcoholic Eosin.

Results

Histology of the retina of these fishes shows variation in the size, shape and distributions of cones. Basically two different types of cone mosaic patterns are identified. One is the row type and the other, the square type. In the row type the cones are arranged in a series of rows. In the square type the double cones are associated with long single cones. The latter are the single cones present in the centre of the square mosaic. In the retina of four species row type of cone mosaics is observed. *S. longiceps* (Pl. I A) and *C. leptolepis* (Pl. I D) possess single cones; however in *C. leptolepis* the single cones are associated with unequal double cones. The Mulliform species *U. vittatus* (Pl. I E) and *U. flavolineatus* (Pl. I F) have only equal double cones, the latter type being found in all the species considered here except *S. longiceps*.

The square type of cone mosaic is found in *E. nigra* (Pl. I C), *S. fuscoguttatus* (Pl. I G), *S. tolu* (Pl. I H), *D. pictum* (Pl. I I) and *T. theraps* (Pl. I J). All these species possess equal double cones associated with long single cones.

S. microlepidotus (pl. I B) does not show a regular pattern of cone mosaic. It has rows of single cones on the edges of double cones and

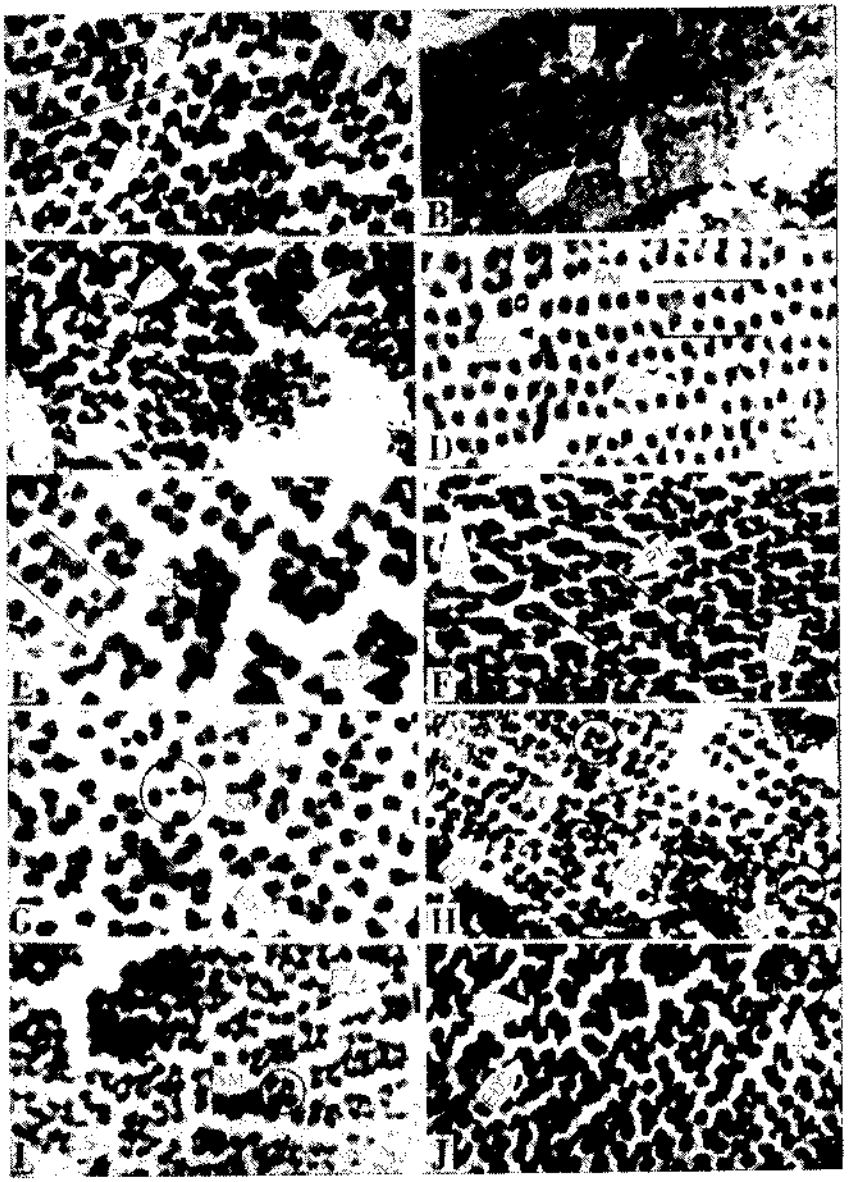

PLATE I Photomicrographs of the tangential sections of the retina of : A. *Sardinella longiceps*, B. *Scomber microlepidotus*, C. *Elacate nigra*, D. *Carans leptolepis*, E. *Upeneoides vittatus*, F. *Upeneoides flavolineatus*, G. *Serranus fasciatiatus*, H. *Synagris tolu*, I. *Diagramma pictum* and J. *Therapon theraps*. (EDC Equal Double Cone, LSC — Long Single Cone, NR — No Regular Mosaic, RM — Row Mosaic, SC — Single Cone, SM — Square Mosaic, UDC Unequal Double Cone and VCL — Visual Cell Layer).

square mosaics with double cones associated with long single cones in the different regions of the retina. Long single cone is conspicuously absent in *S. longiceps* and *C. leptolepis*. However these two species possess additional single cones, which are single cones found at random in the retina.

Discussion

It is evident from the present study that the visual cells in the family Clupidae, Scombridae, Carangidae, Mullidae and Percidae are developed into very clearly distinguishable types. The description of the cone types and the cone mosaics show intergeneric variations that can be related to phylogeny and ecology as well as to the morphology of the cone mosaics of these fishes (Table 1).

(1957 a, b) it is known that the central single cones are the long single cones and the single cone occupying other positions in the mosaics are the short single cones or additional single cones. Mulliformes do not possess single cones as seen in this investigation. Absence of single cones in *U. vittatus* and *U. flavolineatus* might be an adaptation with increase in depth of habitation.

Wunder (1926) and Walls (1942) pointed out the presence of twin cones to be an asset for surface living forms. This has been questioned by Tamura (1957) who found that all cones in some fishes from fairly deep waters (100 to 300 metres depth) are twins. Results of the present study with reference to *U. vittatus* and *U. flavolineatus* in the absence of single cones confirms the view of Tamura (1957). These

Table 1. *Summary of the cone types and cone mosaics in the marine teleost retina of Madras Coast studied*

Species	Cone types			Mosaic pattern			
	S.c.	L.s.c.	Eq.d.c.	Un.d.c.	Row	Sq.	No. reg.
Clupeidae							
S. longiceps	X			X	X		
Carangidae							
C. leptolepis	X		X		X		
Mullidae							
U. vittatus			X		X		
U. flavolineatus			X		X		
Scombridae							
S. microlepidotus	X		X				X
E. nigra		X	X			X	
Percidae							
S. fusconuttatus		X	X			X	
S. tolu		X	X			X	
D. pictum		X	X			X	
T. theraps		X	X			X	

Abbreviations:— S.c.: Single cones; L.s.c.: long single cones; Eq.d.c.: equal double cones; Un.d.c.: unequal double cones; Row: Mosaic composed of rows; Sq: mosaic composed of squares; No. reg.: no regular mosaic found.
X Indicates presence

The single cones

Furst (1904) distinguished differences among various kinds of single cones in *Salmo*. The cone present in the centre of the square was named by him 'mittelzopfen' and the cones present in the corners as "Zwischenzopfen". From the studies of Muller (1952) and Lyall

Mullids are bottom feeders living almost at 100 metres depth. The absence of single cones is quite interesting which may be due to tropical conditions (Tamura, 1957).

All the four species of the family Percidae which have been studied in the present work have a central single cone which could be

classified as long single cone following Engstrom (1963 a,b). The Percids live at different depths *i.e.*, 50 to 100 metres having different adaptations. The central single cones present in this family may be due to the disappearance of the additional single cone during the growth of the eye as described to be the case in *Salmo* (Furst, 1904; Lyall, 1957 a,b). The loss or total absence of the additional single cone is widespread in some groups of fishes but not in others.

The double cones

The view that the double cones are associated with vision in deep waters has been proposed by Walls (1942), Willmer (1953) and Lyall (1957 b). Excepting in *S. longiceps* in which unequal double cones are present, the members of Scombridae, Carangidae, Mullidae and Percidae have equal double cones. The results are in conformity with their phylogeny where the advanced groups have equal double cones having originated from unequal double cones of the lower groups. Functionally the double cones present in lower groups react in lower light intensities than do the long (central) single cones (Walls, 1942).

Cone mosaics

Two types of cone mosaics are identified in the retinas of these teleosts *viz.*, (1) rows of parallely arranged double cones, alternating with rows of single cones (E-type of mosaic of Anctil, 1977) and (2) square type (G. type of cone mosaic of Anctil, 1977). The latter is the advanced type. In the present work the primitive groups *viz.*, the Clupids and the Mullids have the row type. Between these two groups, Clupids with unequal double cone is more primitive than the Mullids, the latter having equal double cones. Single cones are associated with very bright light which explains their presence in *Sardinella* and *Caranx*.

Percids have the advanced type *viz.*, square mosaic pattern with long single cone in the centre of the square. Scombrids though a primitive group compared to Percids have varied mosaic patterns, the pattern being irregular in *S. microlepidotus* and square in *E. nigra*, probably the latter being an advanced genus over *Scomber*.

The eye or regions of eye which are adapted for acute vision is endowed with very regular mosaic, the most regular mosaics being found in fishes feeding on fast moving preys. Thus a regular mosaic is advantageous to visual acuity. A regular distribution of the different visual elements in the retina presumably of differential physiological properties enables recordings of the movements of fast moving objects.

The variation in the teleostean cone mosaics are not only dependent on the ecology of the fish, but are also correlated with the phylogeny of the fish as seen in the preceding account. The retinas of fishes of the advanced family Percidae have the square type of mosaic as seen in this work.

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