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EFFECT OF DIFFERENT LIGHT CONDITIONS ON THE EYES OF SOME NOCTURNAL FISHES

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ABSTRACT

The present investigation is aimed to ascertain the real nature of the eye of nocturnal cat fishes. As light is concerned cat fishes are bizzare in occupying bright light, dim light or dark adaptation. As topic concerns basically comparative study of eyes of Indian nocturnal cat fishes *C. batrachus* and *H. fossilis* have been performed. It is inferred that the eyes of two muddwelling nocturnal cat fish species examined are not degenerate but are specialized for nocturnal habit and bottom living as eye can be functional in dim light to detect the dawn and dusk period. The present work reports the retinomotar responses to constant illumination & constant darkness.

KEYWORDS : Nocturnal fish, Light condition, Degenerate eye, Dawn & dusk, Retinomotar Response

For visual perception of the environment fishes have well developed functional eyes. Under condition of subdued light, rendering vision difficult or impossible, some fishes may have degenerated or completely non-functional eyes, *Bathypterous aubius*. Further cave dwelling fishes and those living in subterranean waters may be blind *Lucifuga dentatus*. Underwater vision depends on condition of water (transparency of water, current of water, depth of water etc), as well as on vision acuity of fish present there. Turbid and rough water may transmit less light than clear and calm water.

In general, lateral eyes provide a binocular vision in fish. In calm water (smooth surface) fish view objects above the water through a circle above each eye, nearly all objects from horizon to horizon are viewed when window is enlarged with increasing depth. While the arial field is neither narrowed nor widened, there may be change in the brightness or distortion of objects with change in depth. Objects appear largest when they are directly overhead. The window is at its best when the fish looks directly upward and not slantingly upward at the water surface. In the latter case, a fish would only see objects of the bottom mirrored at a point. In rough water also, the circular window may break-up and light emitted through ever changing pattern (Fig. 1) Ordinary teleosts have normally developed eyes which they use in perception of near surrounding, finding and capturing their food. Because the fish has no neck, the eyes protrude enough to be so located on the body as to give a full visual field. The position of eyes in fish provide a binocular vision in accordance with specialized habit of fish inspecting more restricted parts of their surrounding such as-

- Forward Eyes for Binocular Front Vision.
- Upward Eyes for Binocular Overhead Vision.
-Bulging Eyes for Wider Field of Vision Below or Above.

Lens being spherical and refractive index of eye coupled with corneal refractive index being the same as of water/ocular humour, the lens must protrude through iris to achieve a wider visual field. For proper vision wave-length and amount of light are important parameters (for detection of food and enemies), but for acute vision (resolution and sensitivity) the accommodation mechanism and retinal specialization, Nearly objects form large and brighter images than those far-away. Nearby objects demand accurate focussing by more precise adjustment. Thus, catching a prey less than one cm away of the snout would require a perfect accommodation of the lens in rostrad caudad direction. Such nearby vision would be sharp and myopic because of the high resolution in the caudad part of the retina. Retinal resolution on the other hand, is inversely related to separable angle and consequently proportional to density of photoreceptor and the size of eye.

Sensory systems have been extensively studied in fishes not only because of a wide general interest in the behavioural and sensory physiology of this group but also because, in many instances, fishes are technically suitable for general studies of sensory systems and have certain receptors not present in other groups of vertebrate.

The structure of eye in fishes is quite similar although there are some differences in details, particularly

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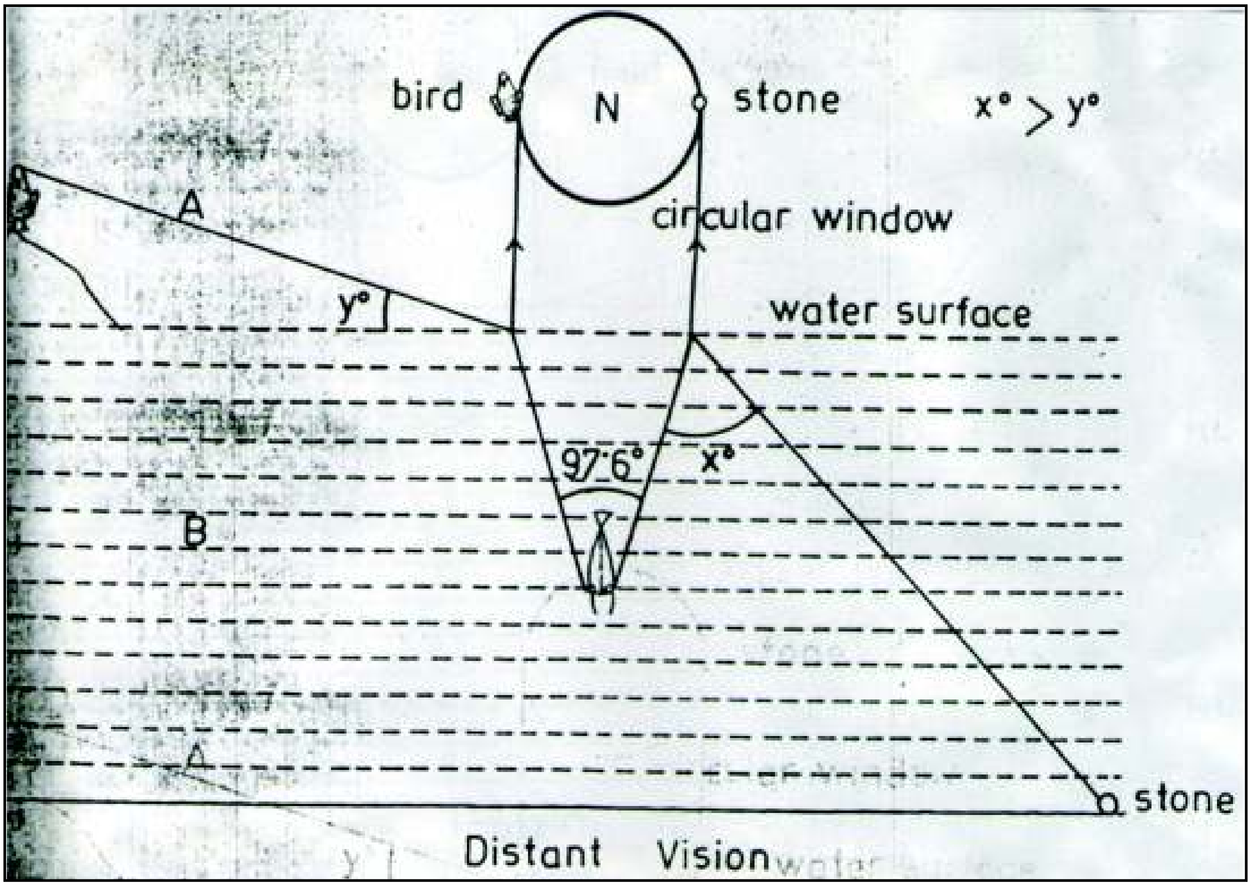

Figure 1

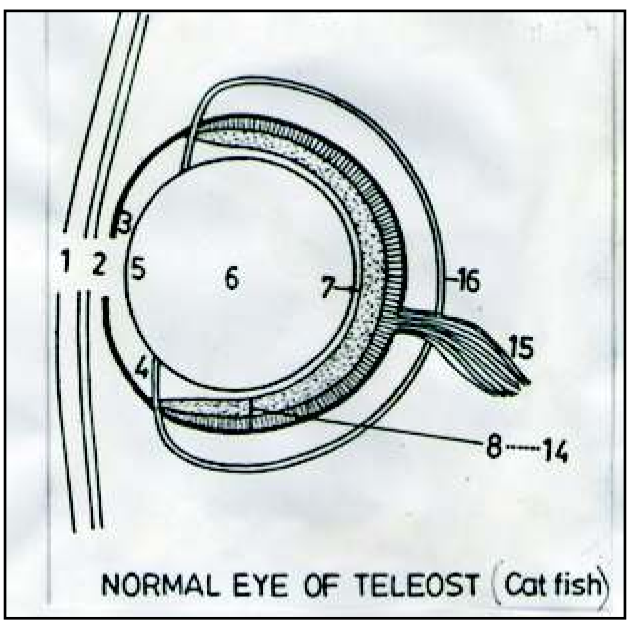

Figure 2

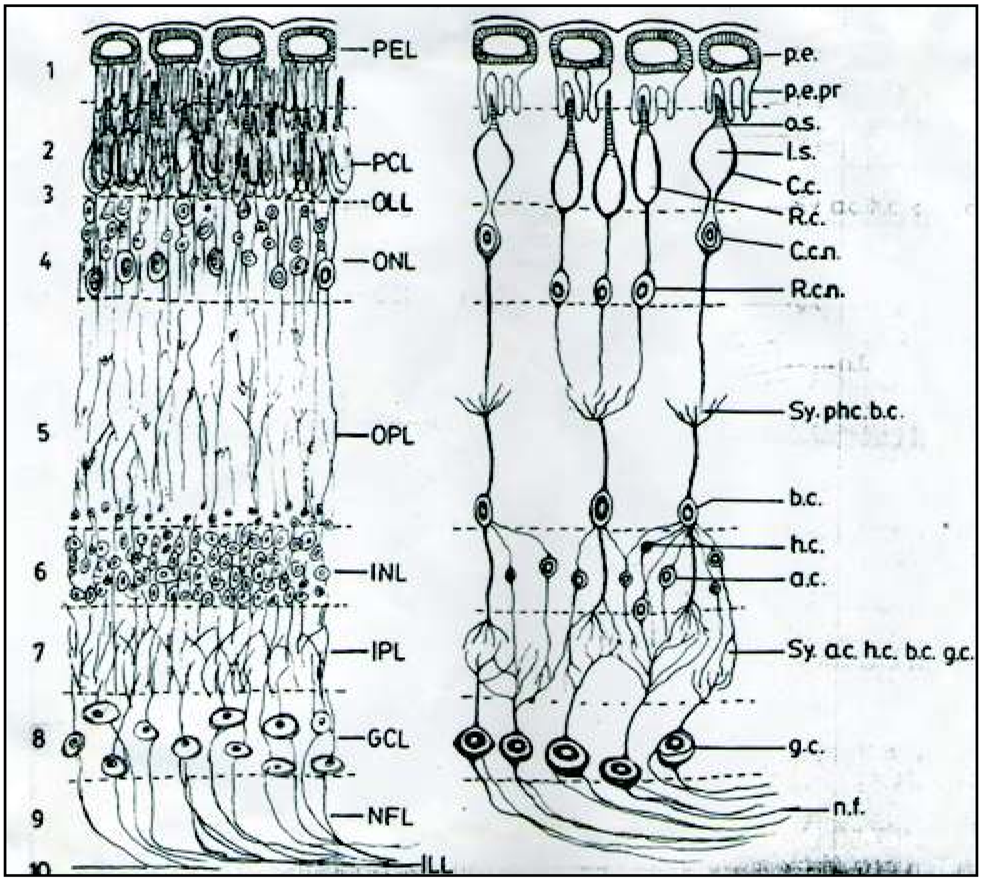

Figure 3

with respect to visual cells in different species.

The retina has been the object of considerable investigation, because it is a readily accessible portion which facilitates the study of neurons, their structure and function. The structural organisation of the retina is highly ordered with the retinal elements arranged in relatively simple layers. The retina is made up of a thin outer and a thick innerwall. A space called ventricular space exist between the two. Thus the retina consists of the following layers which outside - inside are (Fig. 2 & 3)

MATERIALS AND METHODS

Successful survival in any environment depends upon an organisms ability to acquire information from its environment through its senes. Fish have many of the same sense that we have, they can see, smell, touch, feel and taste, and they have developed some sense that we don't have such as electroreception. Fish can sense light, chemicals, vibrations & electricity.

Specimen were collected locally from fishing sites or procured directly from market. These fishes (Live fishes) were found to be hardy withstanding in laboratory conditions and thus suitable for experimentation namely *C. batrachus*. *H. fossilis*. The fishes were maintained in the aquarium under laboratory condition. A ready stock of 25 specimen were generally maintained. Live chironomid larvae earthworm bits or chopped goat liver were found to be readily acceptable food for these fishes.

Fish specimen were anaesthetized with 1:4000 aqueous solution of MS 222 and then examined under a zoom binocular with lateral side facing upward for eye. The eye was removed with care after cutting the optic nerve. Removal of the lens was done at later stage during dehydration with 90% alcohal. A slit was made in the cornea to avoid damage to the retina during microtome sectioning. The section were cut 6 to 8 micron thick and stained with delafield heamatoxylin eosin and heidenhains Azan method humason (1972) the best result was obtained when section were given an overnight treatment with each mordant.

RESULTS

This topic includes the observations on various aspects of the retinal structure and their retraction under different light conditions on Teleost fishes. The experimental conditions consists of exposure of fishes to artificial conditions of continuous illumination (LL) and darkness (DD).

The major emphasis has been on the change of position of photoreceptor cells and pigment epithelium layer, pigments of the retinal layer. The observations are based on microscopic examination of dorsoventrally sectioned eyes, cell counts in the retina, measurement of different layers of retina and movement of photoreceptor cells. The internal structure of the retinal layers of catfishes have been earlier described by Verrier (1927-28), Walls (1942) and discussed by Singh and Munshi (1980) to which reader is referred for details. The present observations are focussed on the nature of the photoreceptor cells and retinomotor responses under normal and certain experimental light canditions, particularly to establish whether they retreat up and down with respect to their normal position in normal light conditions (natural light).

i. Under natural light conditions (pigmented, partially depigmented and completely depigmented).

ii. Under Experimentel Photoperiod Condition:-

(A) Under constant dark condition (pigmented, partially depigmented and completely depigmented condition).

(B) Under constant (DD) illumination conditions (pigmented, partially depigmeted and completely depigmented condition). (LL)

Natural Light Conditions

H. fossilis

Careful examination of serial sections of the retina reveals that it is a well developed thick retina showing an upper pigmented zone, and lower zone devoid of pigments (Fig. 4). An outer limiting membrane is discrimible between the two. The lower row consists of outer nuclear layer, outer plexiform layer, inner nuclear layer, inner plexiform layer, the ganglion cell layer and the nerve fibre layer. The layers of the neural retina except the last two, are very prominent, but the remaining layers are not clearly demarcated. The above description is best revealed when rectinos of normal retina are compared with those of depigmented retina. Complete depigmentati- on alone permits (with 10% Hydrogen Peroxide, overnight) a full and clear view of the photoreceptor cell, The photoreceptor cells are best seen in depigmented sections only. The rod's outer segments could be located, but no cone's outer segments are seen.

The relative thickness (µm) of the various cell layers were measured and the data are given below

(a) 1. Total thickness of retina 274.5 µm
2. 1 to 2 layer thickness 90 µm
3. 1 to 4 layer " 150 µm
4. 4 to 5 layer " 22.5 µm
5. 8 to 9 layer " 4.5 µm
6. 4 to 10 layer " 97.5 µm
7. 6 to 8 layer " 67.5µm

(b) Eye diameter (mm)/body length (cm) 3mm/18cm

(c) No. of rod's/ no. of genglion cells 7-9/8-10

Clarias batrtachus

The histology of the retina as seen in transverse sections is similar to that of Heteropneustes fossilis described above. However, the cell count and relative thickness of the various cell layer are not the same (Fig. 5), and the data on their measurement are given below

(a) 1. Total thickness of retina 247.5 µm
2. 1 to 2 layer thickness 97.5 µm
3.1 to 4 layer " 150 µm
4. 4 to 5 layer " 26.25 µm
5. 8 to 9 layer " 4.5 µm
6. 4 to 9 layer " 97.5 µm
7. 6 to 8 layer " 71.25 µm

(b) Eye diameter (mm)/body length (cm)4mm19cm

(c) No. of rod's/no. of genglion cells 8-9/9-10

II Experimental Photoperiod Condition

Constant Darkness Conditon (DD)

Heteropneustes fossilis

Under constant dark condition, the retina shows that pigments move from processes of pigment epithelium cells to the cell proper, producing narrow dark band(Fig. 6). Rod cells are not demarcated or farther away from the outer limiting membrane which is prominently discernible. The rod's outer segment move close to the outer limiting membrane, which is a clear deviation from their normal

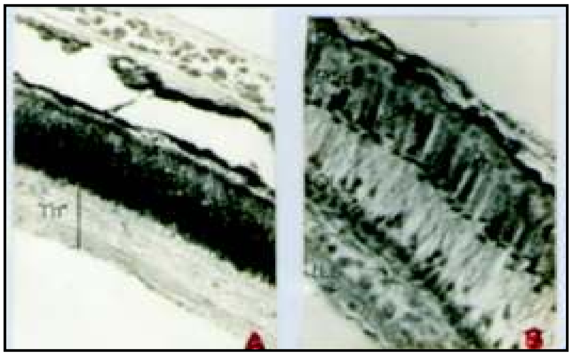

Figure 4 : Cross section of eye of *H. fossilis*
(A)Pigmented Retina Showing Retina
(Upper Eensory Retina Pigmented,
Lower Rural Retina Devoid of Pigment).
Natural light Azan X150 Partially Depigmented Retina
Showing Pigment Epithelial Cells and Its process.
Natural light. Azan X200

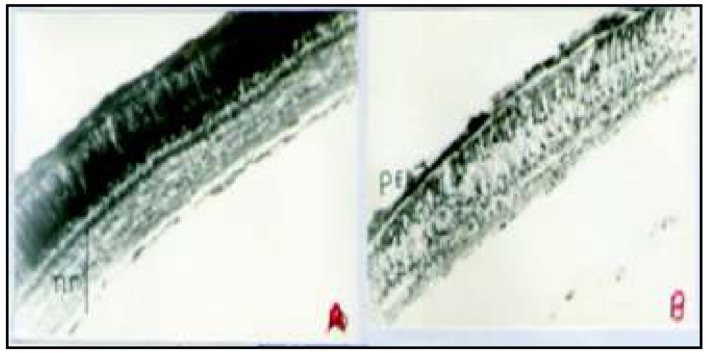

Figure 5 *:* Cross sections of eye of *C. batrachus*
(A) Pigmented retina showing retinal layers
(*S*ame as H. *fossilis*). Natural light. Azan X100
(B)Partially depigmented retina showing pigment
epithelial cells and photo receptor cells.
Natural light. Azan X100

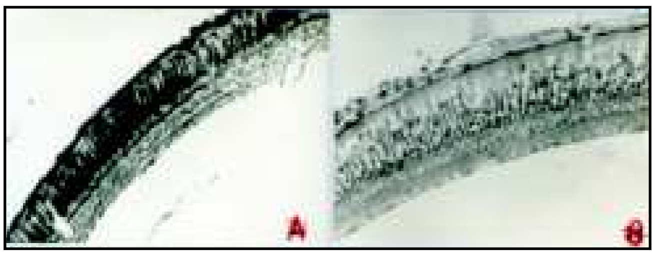

Figure 6 : Cross sections of eye of *H. fossilis*
(A) Pigmented retina shows that pigment move upto cell
proper (pigment epithelial cells) constant darkness.
Azan X100 (B) Completely depigmented retina
shows clear demarcation of rods from their normal
disposition. Constant darkness. Azan X125

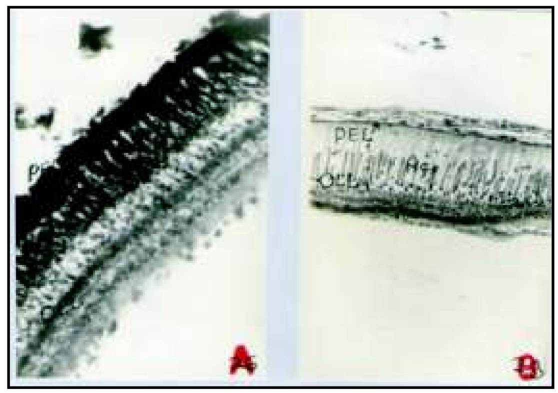

Figure 7 : Cross sections of eye of *C. batrachus*
(A) Pigmented retina constant darkness Azan X150
(B) Completely depigmented.
Constatant darkness. Azan X100

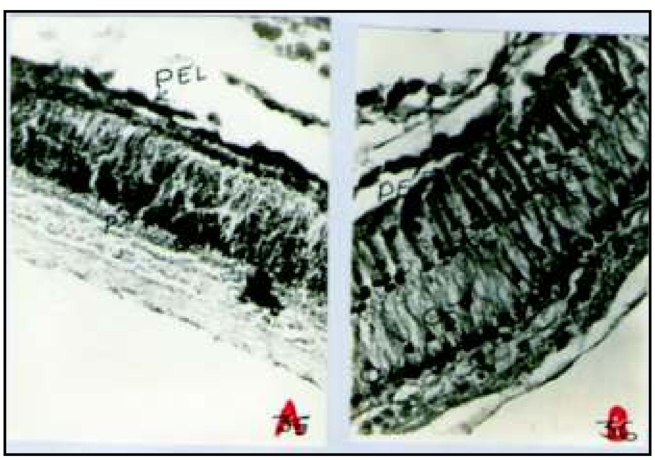

Figure 8 : Cross Eections of eye of *H. fossilis*
(A) Pigmented Retina Constant Illumination. Azan X125
(B) Completely Depigmented Retina,
Constant Illumination. Azan X200

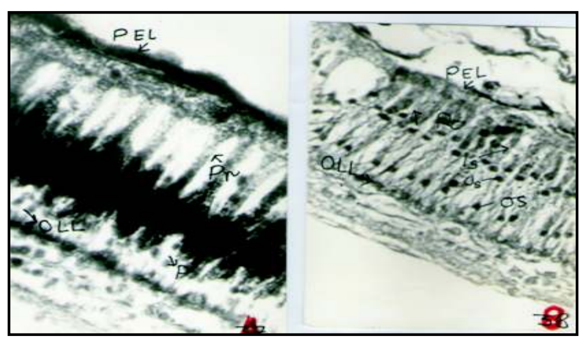

Figure 9 : Cross sections of eye of *C. batrachus*
(A) Pigmented Retina Constant
Illumination Azan X250
(B) Completely Depigmented Retina.
Constant Illumination Azan X200

disposition. Partially depigmented retina shows that pigment do not completely move out of the processes of the pigmented epithelial cells. Some pigments remain in the proximal segment of the cell processes .

Interestingly enough, not with standing the retreated state of the rods outer segment, no cones were visible (although am expended state of cones outer segments, in DD conditions, separating them from those of rods is expected should cones be present in the eye.)

Complete removal of pigments renders rod's outer segments more clearly visible as retreated towards the outer limiting layer outer and inner segments of rods are also clearly visible. The rod's outer pigment come to lie very close to the outer limiting layer.

The measurements of the thickness of different layer of the retina areas

(a) 1. Total thickness of retina		274.5 μm
2. 1 to 2 layer	thickness	90 μm
3. 1 to 4 layer	"	150 μm
4. 4 to 5 layer	"	22.5 μm
5. 8 to 9 layer	"	4.5 μm
6. 4 to 10 layer	"	97.5 μm
7. 6 to 8 layer	"	67.5 μm

(b) Eye diameter (mm).body length (cm) 2.5mm.18cm

(c) No. of rod's/ no. of ganglion cells 8-9/8-9

Clarias batrachus

The histology of the retina as seen in transverse sections is similar or that of Heteropneustes fossilis, described above (Fig. 7). The relative thickness of the various cell layers are not the same, and the data on their measurement are given below

(a) 1. Total thickness of retina		274.5 μm
2. 1 to 2 layer	thickness	150 μm
3. 1 to 4 layer	"	150 μm
4. 4 to 5 layer	"	25.5 μm
5. 8 to 9 layer	"	4.5 μm
6. 4 to 10 layer	"	97.5 μm
7. 6 to 8 layer	"	70.5 μm

(b) Eye diameter (mm)/body lenght (cm)3mm/19cm

(c) No. of rod's/ no. of ganglion cells. 8-9/9-10

CONSTANT ILLUMINATION CONDITION (LL)

The changes evoked by constant illumination condition appear in nature to be just the reverse of that evoked by constant darkness condition. In the case of all the four species of fish examined, namely Heteropneustes fossilis, (Fig. 8) Clarias batrachus (Fig. 9), This is true with regard to movement of pigment of epithelium cells. The outer segments of rods & movement of outer segment of cones. It may be emphasized that even under LL condition, no cones are detected in the case of catfishes and It may be noted that the disposition of retina after exposure to constant illumination condition turns out to be the same as the disposition of retina under natural (day) condition.

The measure of the relative thikness of different cell layers of two fishes are as

Table -I

		H. fossilis	***C. batrachus***
(a) 1. Total thickness of retina		274.5 μm	274.5 μm
2. 1 to 2 layer thickness		90 μm	97.5 μm
3. 1 to 4 layer	"	150 μm	150 μm
4. 4 to 5 layer	"	22.5 μm	26.25 μm
5. 8 to 9 layer	"	4.5 μm	4.5 μm
6. 4 to 10 layer	"	97.5 μm	97.5 μm
7. 6 to 8 layer	"	67.5 μm	71.25μm

Eye diameter (mm)/body length (cm) 2.5mm/18cm 3mm/18cm 6m--m/9cm 4.5mm/15cm No of rod's/ no. of ganglion cells 7-8/8-9 8-9/9-10 7-9/8-9/8-9 7-8/10-11

A comparison of the retinal organisation presently investigated in the two species is summarized in Table-I It is abundantly clear that the two catfishes, namely *Clarias batrachus* and *Heteropneustes fossilis* resemble each other. When fish eye such as that of salmonids, Ali (1971) is taken into account as the standard it is found that the two catfish species in point of retinal organisation same. In the two groups, it is found that the ten layers of the retina differ characteristically with respect to their relative development as seen in transverse section of the retina. The following features are specially noticeable.

The ratio between the thickness of layer 1 to 4 (pigment epithelium layer to outer nuclear layer), to the total thickness (1 to 10) of the retina comes to 1:1.4 for *Clarias batrachus* and 1:1.5 for *Heteropneustes fossilis*. When only the thickness occupied by functional photosensitive pigment (pigment epithelium cell and their processes and outer segments of photoreceptor cells) is taken into account as to its relative development against the total thickness of the remaining retinal layers, it is found that. greater in the two catfish species It may be inferred that when layers 1 and 2 (pigment epithelium layer and photoreceptor cell layer) is considered (particularly when this is viewed togethar with para 1) in catfish species, the part of the retina having neuronic elements inner to outer nuclear layer is less developed. When ratio of the thickness of ganglion cell layer and nerve fibre layer to the total thickness of the retina is taken into account, there is more or less constancy of values for these groups of fishes. When ratio of the thickness of layer 4 and 5 (outer nuclear layer and outer plexiform layer) combine to layer 6,7 and 8 (Inner nuclear layer, inner plexiform layer and layer of ganglion cells) is considered, it is found to be greater in the two catfish species.

From the above it is apparent that the retinal organisation in the two catfish, *Calarias batrachus* and *Heteropneustes fossilis* examined presently deviated from those of the other teleosts examined. The latter have resemblence to the retinal organisation found in typical normal teleost eye as that of salmonids Ali (1971). The salmonids are known to be surface dwelling, fast swimming and diurnal forms which possess acute vision to rely upon in feeding and other activities. However, catfishes show a marked deviation from diurnal forms in the retinal organisation. The two catfish species examined are known to be bottom dwelling and hiding by day, but surface dwelling and active by night. In accordance with this nocturnal way of life, vision apparently is of little use in feeding and other activities. These catfishes are known to possess ampullary electroreceptors besides ordinary neuromasts and taste buds (on barbles) on which these may be relying for feeding and other activities during night. In this background the elucidation of retinal components and their significance has remained an enigma. On the basis of present investigation an attempt is made to throw light on this issue. In retinal, organisation of the presently examined catfishes *C. batrachus* and *H. fossilis* is comparable with that of the bottom dwelling nocturnal glass catfish (non-indian) *Kryptopterus bicirrhis* and crepuscular moon eye *Hiodon tergesius*, Wagner (1990). The eyes of the two catfishes *C. batrachus* and *H. fossilis* presently examined show several features of interest which are elaborated below.

The eyes are sunken and 50 times smaller in relation to the body size or less. In other teleosts which have normal eye the ratio generaly comes to 1:30 or more.

The eyes are covered by rather a thick translucent covering, the corneal epithelial and not by a transparent one.

The lens is large.

The retina lack cones and it is a pure rod retina.

The rods possess very large outer segments, which make them look big.

The rod/ganglion-cell ratio is 1.5:1.

Retinomotor movements is response to photoperiod are clear and positive.

The eye of the catfish examined seems to be poorly developed from ordinary vision standpoint, in being smaller in possessing translucent covering Nayar (1951), lacking cones and being poorly organised retina. These features may be regarded as degenerative changes, Day (1958) preventing normal (diurnal) colour vision and image formation. However, preponderance of rods and ganglion cells (at density not less than normal) do point some kind of visual function other than image formation and colour vision. Pure rod retina coupled with large lens and retinomotor moverments strongly support such a contention, that the eye probably can still functin in dim-light and can detect dim-ligh, of dawn and dusk (twilight) Eriksson (1973). It may function in monitoring photoperiodic changes in the environment at sunset (dusk twilight, when day passes into night) and sun-rise dawn twilight, when night passed into day). It may still function if not in object detection by image formation, to detect moving objects over head by shadow detection. Both these functions seemingly have clear adaptive value, ecologically speaking, for these twilight-active nocturnal fishes, Hobson(1972).

The eye of *Clarias batrachus* and *Heteropneustes fossilis* by no measns be regarded as degenerate. Morphological evidence suggests, that they may be specialised for their peculiar habit and habitat, Day (1958). According to Ali (1971), rods can detect movements and large objects such as another fish in the same school, or prey like Daphina by silhouette or movement detection.

Strangely, Singh and Munshi (1980) found that the eye of *Clarias batrachus* and of other mud-dwelling fishes possess mostly cones as photoreceptors, holding that cones function in dim-light. Present observations are not consistent with the findings of Singh and Munshi (1980). Earlier Verrier (1927) has also mentioned the presence of only rods in the eye of *Clarias batrachus*.

It may be presumed that for these two nocturnal catfishes eyes are of no use in their nocturnal activities, feeding included. Vision dependent feeding if at all, may be taking place at sunset when these carnivorous fish are rising up and other diurnal fish are withdrawing from the surface. Silhouette/shadow overhead movement of the descending fish could be easily detected by the rods in the retina of these two catfishes as they are ascending the column of water for purpose of prey capturing.

According to Ali et al. (1961), sparseness of cones together with abundance of rods is characteristic of the retina of the vision-dependent fish. By comparison, the two nocturnal catfish species presently examined, show loss of cones, which can be said to be indicative of a degenerative change.

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