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'Yellow Lens' Eyes and Luminous Organs of *Echiostoma barbatum* (Stomiatoidei, Melanostomiatidae)

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Echiostoma is a genus of rare deep-sea fish belonging to the family Melanostomiatidae (suborder Stomiatoidei), which inhabits the mesopelagic zone (ca. 200～1000 m) (Morrow and Gibbs, 1964). During the R. V. Hakuhō Maru Cruise KH72-1, I found that *Echiostoma barbatum* has bright yellow lenses in the eyes. So far yellow lenses have been observed exceptionally in the deep-sea fishes, i.e. in *Chlorophthalmus* spp. (Denton, 1956; Somiya and Tamura, 1971; Somiya, 1977), *Argyropelecus affinis* (Somiya, 1976) and *Scopelarchus analis* (Muntz, 1976).

In previous papers, I suggested an active function of the yellow lens in close association with bioluminescence (Somiya, 1976, 1977). Muntz (1976) has also mentioned its function in connection with bioluminescent camouflage in some mesopelagic animals. But the definite role of yellow lenses in some deep-sea animals is still obscure. The present paper is a study of the eyes and luminous organs of *Echiostoma barbatum*, made to contribute to further discussion of the function of yellow lenses.

Observation

Material. One specimen of *Echiostoma barbatum* was caught by Isaacs-Kidd midwater trawl at a station in the eastern Indian Ocean (location 11°54.6′S, 119°57.1′E, date 27 June, 1972, time 0505～0745, depth 0～1480 m).

A left view of *Echiostoma barbatum* (220 mm in standard length) is shown in Fig. 1. The fish has typical lateral eyes with normal shape, and in fresh states the external appearance of the eyes was slightly yellow in color. Fig. 2 shows the bright yellow lens of this fish, which was taken out from the eye cup.

Retinal histology. After fixing in 10% formalin, the eye cups were dehydrated in alcohol and embedded in paraffin. Serial 8 μm sections were made and stained with Meyer's acid-hemalum and eosin. The retina (Fig. 3) showed fundamentally the same structure as in *Stomias boa* (Stomiatoidei, Stomiatidae) (Munk, 1963). The pigment epithelium was provided with short pigmented processes. Cones were absent and only rods were located in two distinct superposed layers. There was no difference in length between the outersegments of the inner (vitread) layer and those of the outer (sclerad) layer. The thickness of the retina in the fundus was ca. 120 μm.

Luminous organs. Macroscopic observations on luminous organs were made in the

Fig. 1. Left view of the head of *Echiostoma barbatum*, 220 mm in standard length.

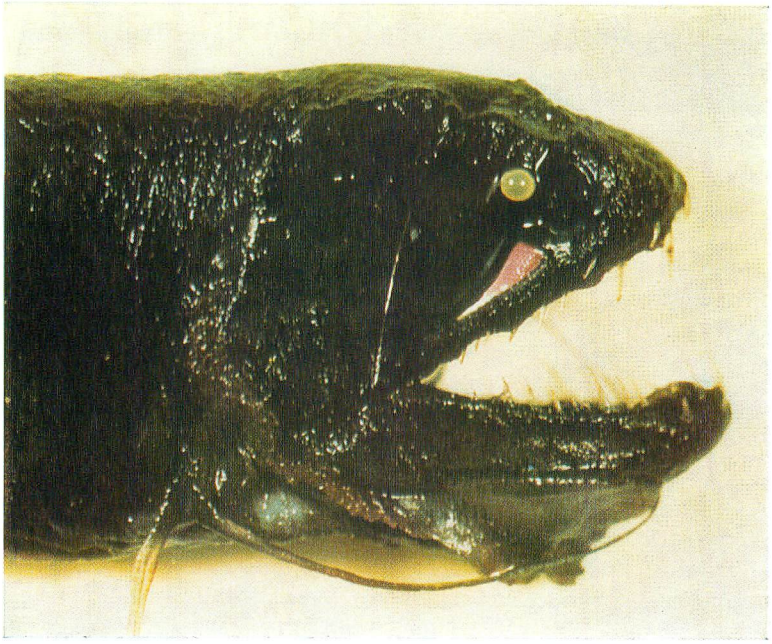

Fig. 2. Right view of *Echiostoma barbatum*, showing the enucleated yellow lens. Note the postorbital light organ with red filter.

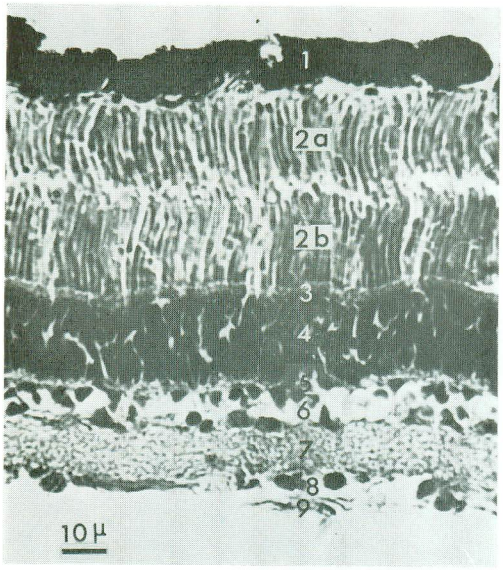

Fig. 3. Retina of *Echiostoma barbatum*. 1: pigment epithelium; 2a: sclerad layer of rod outersegments; 2b: vitread layer of rod outersegments; 3: outer limiting membrane; 4: outer nuclear layer; 5: outer plexiform layer; 6: inner nuclear layer; 7: inner plexiform layer; 8: ganglion cell layer; 9: nerve-fiber layer.

specimen preserved in alcohol. Four kinds of organs were distinguished. 1) Postorbital light organ of an elongated, triangular shape, and its length ca. 26% of head length. 2) Four regular rows of serial large photophores were observed on the ventral part of the body. 3) Numerous small photophores (dark and visible to the naked eye) on the body surface were observed in two groups. The first group of photophores was arranged in a regular vertical series which extends from the opercles to the caudal fin at intervals on the lateral side of the body above a lateral series of large body photophores. Photophores of the second group were distributed dispersedly on the head and ventral side of the trunk between lateral and ventral rows of serial large body photophores. This type of photophores was also observed on the epi-scleral region of the eyeball and the mucous membrane on the roof of mouth. 4) Numerous minute, unpigmented luminous organs were found along the dorsal and ventral margins of the body, and on all the fins.

Discussion

One of the most remarkable features of

larger stomiatoid fishes is their multiplicity of luminous organs. *Echiostoma barbatum* exhibited four kinds of luminous organs. A detailed observation of their bioluminescent color from the luminous organs in living *E. barbatum* has been reported by Beebe and Crane (1939).

Concerning the function of bioluminescence of *Echiostoma barbatum*, recent studies on deep-sea fish bioluminescence (Denton et al., 1972; O'Day, 1973; Young and Ropper, 1977) may indicate as follows: Ventral bioluminescence produced by serial large and numerous small photophores on the ventral part of the body will certainly contribute to bioluminescent camouflage. Fins and "bands" along the dorsal and ventral margins of the body, which were spotted by numerous minute, unpigmented luminous organs, may render the outline of the fish visible (luminescent silhouetting), but the function of such luminescent silhouetting is still obscure.

Furthermore, *Echiostoma barbatum* may use the red bioluminescence from the large postorbital light organ in searching for prey (or as predator protection) without being noticed by the prey (or predator), because most of deep-sea fishes (except for some larger stomiatoids) are largely insensitive to red light. Their red bioluminescence could also be employed in intraspecific communication. Indeed in the eyes of some larger stomiatoids, e.g. *Pachystomias* and *Aristostomias*, Denton et al. (1970), O'Day and Fernandez (1974) and Knowles and Dartnall (1977) found the visual pigment especially sensitive to red bioluminescence emitted from their own suborbital light organ and discussed the ecological significance of it (see also Denton, 1971).

In previous papers on the yellow lens eye of deep-sea fish (Somiya, 1976, 1977), I discussed the discrepancy existing between sensitivity increasing structures (tubular eye in *Argyropelecus*, and tapetum and grouped retina in *Chlorophthalmus*) and light-absorbing yellow lenses. I interpreted the discrepancy as follows. The yellow lens acts as a preretinal-color filter and cuts out a shortwave-light. The sensitivity increasing structure only works on the transmitted "longwave-light". These interpretations indicate that such deep-sea fish with yellow lenses may have a strategy to use a dim but an important "longwave photo-signal" for their deep-sea lives, which is detectable by the aid of the sensitivity increasing structure. In previous studies, I discussed an active function of the yellow lens in close association with bioluminescence.

In the eyes of *Echiostoma barbatum*, the same discrepancy exists between sensitivity increasing structures, i.e. superposed layers (two banks) of rods (see Munk, 1966; Locket, 1975), and the light-absorbing yellow lens. This discrepancy recalls an interrelationship between the red bioluminescence and the red sensitive eye. That is, *E. barbatum* has the specialized eye which is necessary to detect red light which reflects from the prey (or the predator) and acts as an intraspecific signal. In such visual perception, the yellow lens may act as a preretinal-color filter in the first place and then the superposed rod retina containing the red sensitive visual pigment only works on the transmitted longwave-light especially red light. In this way the yellow lens and the retinal specialization may actively function to find the red signal selectively in such deep-sea environmnets.

Acknowledgments

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Echiostoma barbatum (ホテイエソ科) の"黄色水晶体" 眼と発光器

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KH72-1 次白鳳丸航海(東南アジア海域)でホテイエソ科 Melanostomiatidae の *Echiostoma barbatum* が一尾採集された．そして，その眼に黄色水晶体が観察された．現在のところ，深海魚の黄色水晶体は例外的に報告されているだけで，その生態学的な役割についてもはっきりしていない．そこでその眼の組織学的観察と発光器の肉眼的観察を行ない，あわせてその黄色水晶体の機能についての考察を行なった．

網膜は明暗視だけに関与する桿体細胞からできており，その視細胞の配列は他の多くの浅海魚のものとは異なり二層構造を形成していた．また体表には四種類の発光器が観察された。即ち，1) 頬発光器，または眼窩後部発光器 (postorbital light organ), 2) 体側の発光器, 3) 体表の小型発光器, 4) 微小な球状発光器．黄色水晶体の機能を眼窩後部発光器との関連で考察した．

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