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Note

Morphogenesis of the Eye of Brown Croaker (*Miichthys miiuy*)

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Abstract : Eye growth and lens diameter of brown croaker *Miichthys miiuy* were positively allometric between hatching and 180 days post-hatch (d.p.h.). Eye growth in relation to head length and head height was nearly isometric. Eyes were formed completely at 14 d.p.h. At this age, the eye has a crystalline lens, an optic nerve fiber layer, a ganglion cell layer, an inner plexiform layer, an inner nuclear layer, an outer plexiform layer, an outer nuclear layer, an outer limiting membrane, and a pigment epithelium. The essential demands that must be met by the retina in this species pertain to light sensitivity and spatial resolution.

Key words : brown croaker, eyes and lens diameter, head dimensions, retina structure, total length

1. Introduction

In most species, vision is considered the dominant sense during the larval period, as it is required for feeding, orientation, schooling, and avoiding potential predators (Rodriguez and Gisbert 2001). Although retinal structure in teleosts does not differ in principle from that found in other vertebrates, it appears to be more difficult than it is with other vertebrate species to present a general model for the architecture of the fish retina. This is due to the enormous number of fish species and to the tremendous diversity of habitats, behaviors, and life histories (Wagner 1990). The consequences of behavioral and/or environmental factors for the structure and function of the visual system have been referred to as 'visual ecology' (Walls 1942; Lythgoe 1979).

The brown croaker *Miichthys miiuy* (Basilewsky) belongs to the family *Sciaenidae* and inhabits water at depths of 15 to 20 m at the bottom of flat tidal regions. The spawning season is from September to October. This species is distributed in the Yellow Sea, the Southern Sea of Korea, the Southwest Sea of Japan, and the South China Sea (Choi *et al.* 2002).

Previous studies of brown croaker have investigated its developmental ecology and early life growth (Seo 2004) but information on aspects of its visual ecology and development are lacking. Consequently, the aim of this study was to describe the histo-morphological development of the eyes in brown croaker larvae and juveniles (180 days post-hatch, d.p.h.) to determine ocular organization throughout early ontogeny.

2. Materials and methods

The experimental animals were laboratory-bred offspring of brown croaker, which were raised in the Gyeongsangnam-do Fisheries Resources and Research Institute, Korea, following the standard methods of artificial propagation. Newly hatched larvae were sampled daily from hatching to 10 d.p.h., at 2-day intervals from 10 to 50 d.p.h., and at 10- to 20-day intervals from 50 to 180 d.p.h. Twenty individuals were randomly selected at each sampling.

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Growth in total length was examined. To determine allometric growth of the eye in relation to body morphometrics, total length, head length, and head height for 50 freshly sampled larvae at different stages were measured to the nearest 0.01 cm using digital vernier calipers (CD-20CP; Mitutoyo, Kanagawa, Japan).

For the histological observation of the eyes, samples were fixed in 10% neutral formalin after measuring eye and lens diameter. After being fixed in Bouin's fixative for 24 h, eyes extracted from specimens ranging from hatching to 36 d.p.h. (head region excluded) and from 36 to 180 d.p.h. were processed for histological sectioning by routine dehydration and paraffin embedding procedures. Cross sections of 4 to 6 μm thickness were stained with Mayers hematoxylin and eosin phloxine B solution for the examination.

3. Results and discussion

In many teleosts, the eyes continue to grow even in adulthood, but growth of the ocular components is balanced so that optical properties do not change dramatically (Powers

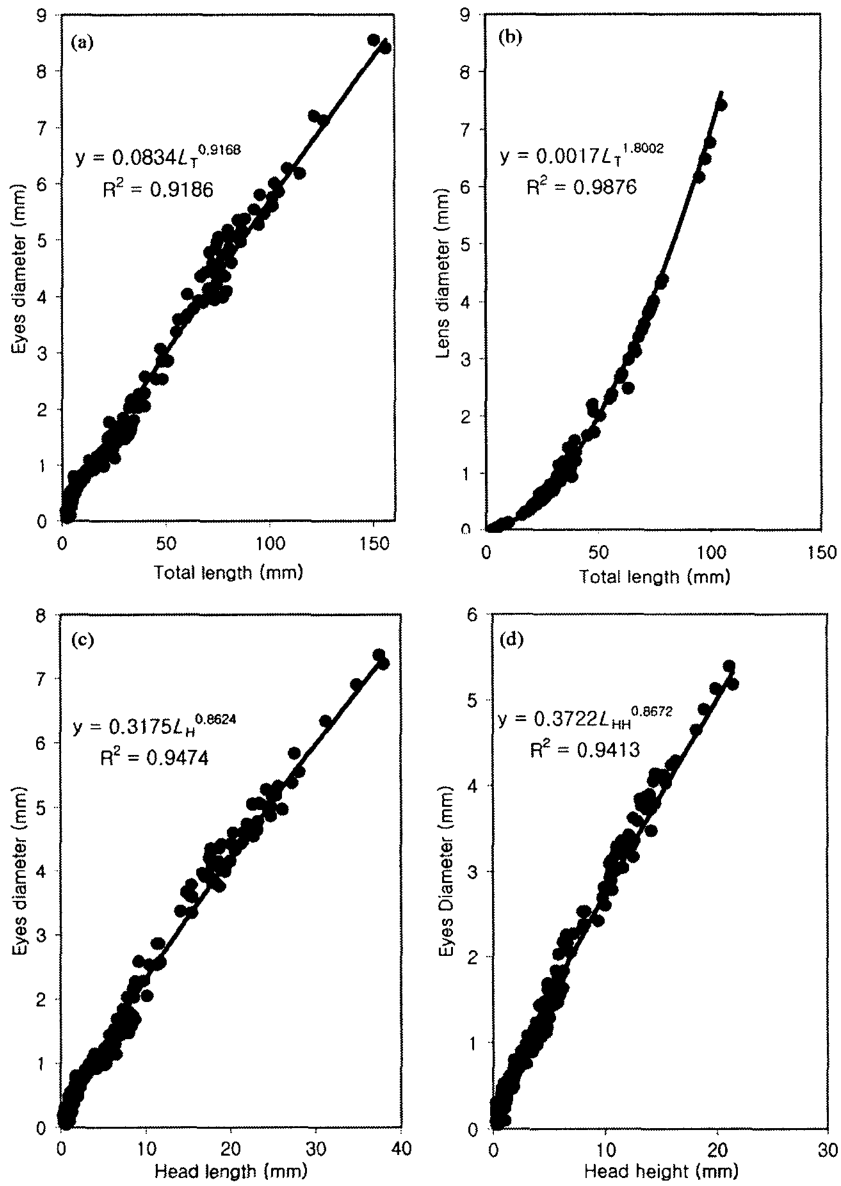

Fig. 1. Relationship between (a) total length and eyes diameter, (b) total length and lens diameter, (c) head length eyes diameter, and (d) head height and eyes diameter of the *miichthys miiuy*.

et al. 1988; Raymond *et al.* 1988; Powers and Raymond 1990). Total length increases indicate continuous growth of fish, as described as $L_T = 1.5409t^{0.7111}$ ($R^2 = 0.9631$). Eye diameter growth of brown croaker in relation to total length (L_T) was nearly isometric ($y = 0.0834L_T^{0.9168}$; $R^2 = 0.9186$; $n = 650$; Fig. 1(a)), while the allometric relationship between lens diameter and total length was positive ($y = 0.0017L_T^{1.8002}$; $R^2 = 0.9876$; $n = 400$; Fig. 1(b)). Eye diameter growths in relation to head length (L_H) and head height (L_{HH}) from hatching to 180 d.p.h. became isometric ($y = 0.3175L_H^{0.8624}$, $R^2 = 0.9474$, $n = 650$; $y = 0.3722L_{HH}^{0.8672}$; $R^2 = 0.9413$, $n = 650$; Fig. 1(c) and (d)).

From hatching to 2 d.p.h. (0.88-2.65 mm L_T), the eye was a solid strand of cerebral tissue consisting of a rudimentary retina lined by neuroblastic cells and a pseudostratified epithelium. The lens began to be formed at 3 d.p.h. (2.58-2.93 mm L_T), and the eye was formed completely at 14 d.p.h. (4.11-4.54 mm L_T).

The histological structure of completely formed eyes (14 d.p.h., 4.11-4.54 mm L_T) comprised nine layers: (1) the crystalline lens (L) consists of a sheath with a stratified cuboidal epithelium and nucleated fiber cells; (2) the optic nerve fiber layer (ONFL) consists of the nerve fibers leading to the optic tract; (3) the ganglion cell layer (GCL) contains the perikarya of ganglion cells and displaced amacrine cells. While the former typically exhibits large cell bodies with prominent nuclei, there are also smaller subtypes that are difficult to distinguish from amacrine cells without additional histological markers; (4) the inner plexiform layer (IPL) consists of reticular tissue; (5) in the inner nuclear layer (INL; with horizontal, amacrine, and bipolar cells), the cell bodies of horizontal cells can easily be recognized by their nuclei, which are situated next to the outer plexiform layer and orientated parallel to the retinal surface. Bipolar cell perikarya are generally identified on the basis of their narrow rim of cytoplasm and their round and mostly dark-staining nuclei; these properties distinguish them from amacrine cells, which are found at the inner border of the inner nuclear layer and which are typically characterized by round perikarya with ample cytoplasm and lightly stained nuclei; (6) the outer plexiform layer (OPL) is organized as a thin reticular tissue; (7) the outer nuclear layer (ONL) is formed by two types of photoreceptor cells, rods, and single cones. There is a cylindrical outer segment, an ovoid ellipsoid and a filamentous myoid form the eosinophilic part of the rods, while the nuclei are basophilic and round; (8) the outer limiting membrane (OLM) consists of cone photoreceptors with a shorter tapered outer segment, larger ovoid ellipsoids containing an oil droplet, and nuclei. Outer segments of photoreceptors are partially enveloped by projections of the pigment epithelium; (9) the pigment epithelium (PE) is organized as a single layer of cuboidal cells.

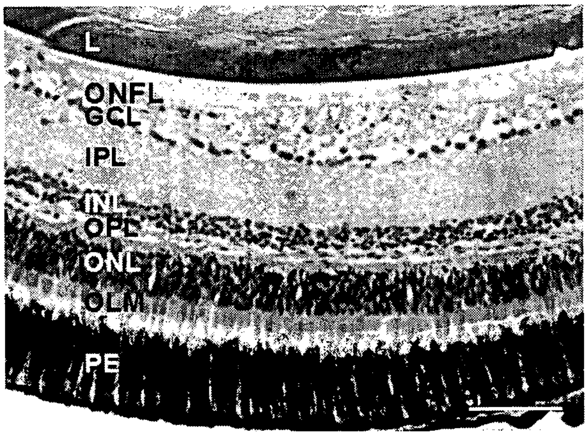

Fig. 2. Light micrograph showing a transverse section of the eye of *Miichthys miiuy* at 14 d.p.h. Lens (L), optic nerve fiber layer (ONFL), ganglion cell layer (GCL), inner plexiform layer (IPL), inner nuclear layer (INL), outer plexiform layer (OPL), outer nuclear layer (ONL), outer limiting membrane (OLM), and pigment epithelium (PE) (H-E). Bar is 200 μm.

From 14 d.p.h. to the end of the study, the only changes detected in the eyes of larvae were an increase in the number and size of cells, particularly in the retina, where an increase in photoreceptor cells and melanin in the pigmented epithelium occurred. Similar observations have been reported for Siberian sturgeon *Acipenser baeri* (Rodriguez and Gisbert 2001).

The retinal morphology of a given species is not determined by its taxonomic classification but rather by the functional requirements imposed upon the visual system by ecological and ethological factors (Wagner 1973, 1980, 1990; Wagner and Douglas 1983; Kawamura *et al.* 2003). The essential demands that must be met by the retina in brown croaker are related to light sensitivity and spatial resolution.

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References

Choi, Y., J.H. Kim, and J.Y. Park. 2002. Marine Fishes of Korea. Kyohaksa Publ. Co., Ltd., Seoul, Korea. 352 p.

Kawamura, G., S. Masuma, N. Tezuka, M. Koiso, T. Jinba, and K. Namba. 2003. Morphogenesis of sense organs in the bluefin tuna *Thunnus orientalis*. p. 186-201. In: *The Big Fish Bang*. ed. by H.I. Browman and A.B. Skiftesvik. Inst. Mar. Res., Bergen, Norway.

Lythgoe, J.N. 1979. The Ecology of Vision. Clarendon Press, Oxford. 261 p.

Powers, M.K. and P.A. Raymond. 1990. Development of the visual system. p. 419-443. In: *The Visual System of Fish*. eds. by R. Douglas and M. Djamgoz. Chapman and Hall, London.

Powers, M.K., C.J. Bassi, and P.A. Raymond. 1988. Lighting conditions and retinal development in goldfish: absolute visual sensitivity. *Invest. Ophthalmol. Vis. Sci.*, 29, 37-43.

Raymond, P.A., P.F. Hitchcock, and M.J. Palopoli. 1988. Neuronal cell proliferation and ocular enlargement in Black Moor goldfish. *J. Comp. Neurol.*, 276, 231-238.

Rodriguez, A. and E. Gisbert. 2001. Morphogenesis of the eye of Siberian sturgeon. *J. Fish Biol.*, 59, 1427-1429.

Seo, D.C. 2004. Development ecological and early growth of brown croaker, *Miichys miiuy*. Ph.D. Thesis, Yosu National Univ., Korea. 144 p.

Wagner, H.-J. 1973. Darkness-induced reduction of the number of synaptic ribbons in fish retina. *Nature New Biol.*, 246, 53-55.

Wagner, H.-J. 1980. Light dependent plasticity of the morphology of horizontal cell terminals in cone pedicles of fish retinas. *J. Neurocytol.*, 9, 573-590.

Wagner, H.-J. 1990. Retinal structure of fishes. p. 109-157. In: *The Visual System of Fish*. eds. by R. Douglas and M. Djamgoz. Chapman and Hall, London.

Wagner, H.-J. and R.-H. Douglas. 1983. Morphologic changes in teleost primary and secondary retinal cells following brief exposure to light. *Invest. Ophthalmol. Vis. Sci.*, 24, 24-29.

Walls, G.L. 1942. The Vertebrate Eye and Its Adaptive Radiation. Facsimile edition, Hafner Publishing Co., New York. 302 p.

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