Journal of FISH BIOLOGY

fsbi An International Society for Fish Biology

Journal of Fish Biology (2015)
doi:10.1111/jfb.12842, available online at wileyonlinelibrary.com

BRIEF COMMUNICATION

Ocular anomaly in Atlantic midshipman *Porichthys plectrodon* (Batrachoidiformes: Batrachoididae) from the Mississippi Canyon, north-central Gulf of Mexico

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(Received 27 April 2015, Accepted 19 October 2015)

The first record of an ocular anomaly in Atlantic midshipman *Porichthys plectrodon* (Batrachoidiformes: Batrachoididae) is reported from a specimen captured in the Mississippi Canyon. The anomalous specimen was bilaterally anophthalmic and the nape and dorsum were darkly pigmented but alizarin staining and histology revealed a complete eye embedded within the cranium beneath a markedly thickened dermal component of the cornea, along with seemingly minor elaboration of the choroid rete between the cornea and lens. Aetiology is indeterminate and beyond the scope of the study materials but barotrauma, infectious disease and previous wounding are doubtful.

Key words: abnormality; eye; fish; histology; lesion.

Ocular anomalies in wild-caught fishes seldom are reported (McElwain *et al.*, 2013), perhaps because the affected fish is theoretically more prone to wasting and predation such that its capture in the vast ocean comprises luck (Hargis, 1991; Blaylock & Bullard, 2014). Documenting putative anomalies among Gulf of Mexico fish populations using detailed gross and microscopic observations is important because of claims that fishes there exhibited so-called lesions and deformities following the 2010 BP Deepwater Horizon oil spill (DHOS). Yet, nearly 5 years later, these alleged DHOS-related anomalies remain histopathologically undiagnosed in the peer-reviewed literature. Because eye abnormalities suggest poor health and an inferior seafood product, they affect the aquaculture, seafood and aquarium industries. The fish eye may also serve as a coarse bio-indicator of disease and nutrition status among wild and captive-raised fish populations (Hargis, 1991; Williams & Whitaker, 1997; Sun *et al.*, 2009). This study describes an ocular anomaly in a specimen of Atlantic midshipman *Porichthys plectrodon* Jordan & Gilbert 1882 (Batrachoidiformes: Batrachoididae) from the north-central Gulf of Mexico.

The specimen of *P. plectrodon* with the ocular anomaly (male; 104 mm fork length, L_F; 11·3 g wet mass) was collected as by-catch from a commercial shrimp

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trawler fishing near the Mississippi Canyon (28·4300° N; 89·4199° W; 56 km south of the Mississippi River mouth off Louisiana, U.S.A.) on 29 September 2013. For comparative purposes, five specimens of *P. plectrodon* [none presenting the ocular anomaly (normal specimens), three males and two females; $L_F = 94–124$ mm (mean ± s.d. = 110 ± 10 mm); wet mass = 6·9–16·3 g (mean ± s.d. = 12·5 ± 4·3 g)] were processed in parallel. These fish were originally collected by routine independent fisheries monitoring trawl activities conducted by the U.S. National Oceanographic and Atmospheric Administration (NOAA) R.V. *Gordon Gunter* in the Gulf of Mexico off Florida in 2012. All specimens were processed routinely in the field by slitting the abdomen and immersion in 10% neutral buffered formalin (NBF). In the laboratory, specimens were photographed and then bisected in the sagittal plane such that the sinistral and dextral halves of the cranium could be processed for alizarin staining and histopathology, respectively. In addition, two normal specimens were left intact and parsed for alizarin staining and histopathology. Also for comparative purposes, conspecific vouchers were examined and sourced from the Auburn University Museum of Natural History (AUMNH, Auburn, Alabama, U.S.A.), Louisiana State University Museum of Zoology (LSUMZ, as digital images, Baton Rouge, Louisiana, U.S.A.) and the NOAA Southeast Fisheries Science Center (SFSC, Pascagoula, Mississippi, U.S.A.). Fish were identified as *P. plectrodon* (Collette, 2002) by the combination of having a scale-less body, canine-like teeth, branchiostegal photophores forming a U-shaped and forward-directed apical commissure, 16–18 (mean 17) pectoral-fin rays, two dorsal-fin spines (both solid and lacking venom glands), 36–38 (mean 37) dorsal-fin rays and 34 anal-fin rays (one specimen had 29 dorsal-fin rays), as well as by lacking an axillary pore behind the pectoral fins and subopercular spines. Common and scientific names, including taxonomic authorities and dates, follow Collette (2002), Eschmeyer (1998) and Eschmeyer & Fong (2015). Osteological terms are taken from Gregory (1959), and the detailed anatomical description of the syncranium of the oyster toadfish, *Opsanus tau* (L. 1766), (Batrachoidiformes: Batrachoididae) was used to locate and identify cranial bones in the studied specimens of *P. plectrodon*. Terminology for the fish eye follows Nicol (1989) and McElwain *et al.* (2013), and fish were photographed, stained and sectioned (McElwain *et al.*, 2013). Voucher materials, including histological sections and alizarin-stained and cleared fish, were deposited in the AUMNH (collection numbers 66301–66302).

Results from gross inspection, alizarin staining and clearing, and histology follow. Grossly, normal specimens [Fig. 1(a)–(d)] have a dorsoventrally compressed syncranium, with the orbit partly comprising the notched lateral edges of the neurocranium and the pupil principally directing dorsally. The eye telescopes by a diminutive fleshy extension (eyestalk), and the skin associated with the globe is accordingly smooth about the base of the eyestalk or slightly in-folded surrounding the eyestalk aperture, depending on eyestalk confirmation at fixation. The eyestalk is evidently articulated by at least one pair of muscle fascicles extending laterally from the posterior pole of the globe and, in normal specimens, the globe of the eye can be markedly extended from the neurocranium or nearly flush with its surface. The globe of the eye is well defined and easily visualized [Fig. 1(d), (i)], and the pupil is centred on the typical pattern of ray-like ocular melanosomes [Fig. 1(a), (b), (i)]. The cornea (the transparent extension of the sclera between the lens and dermal component of the cornea) is thin [Fig. 1(i)].

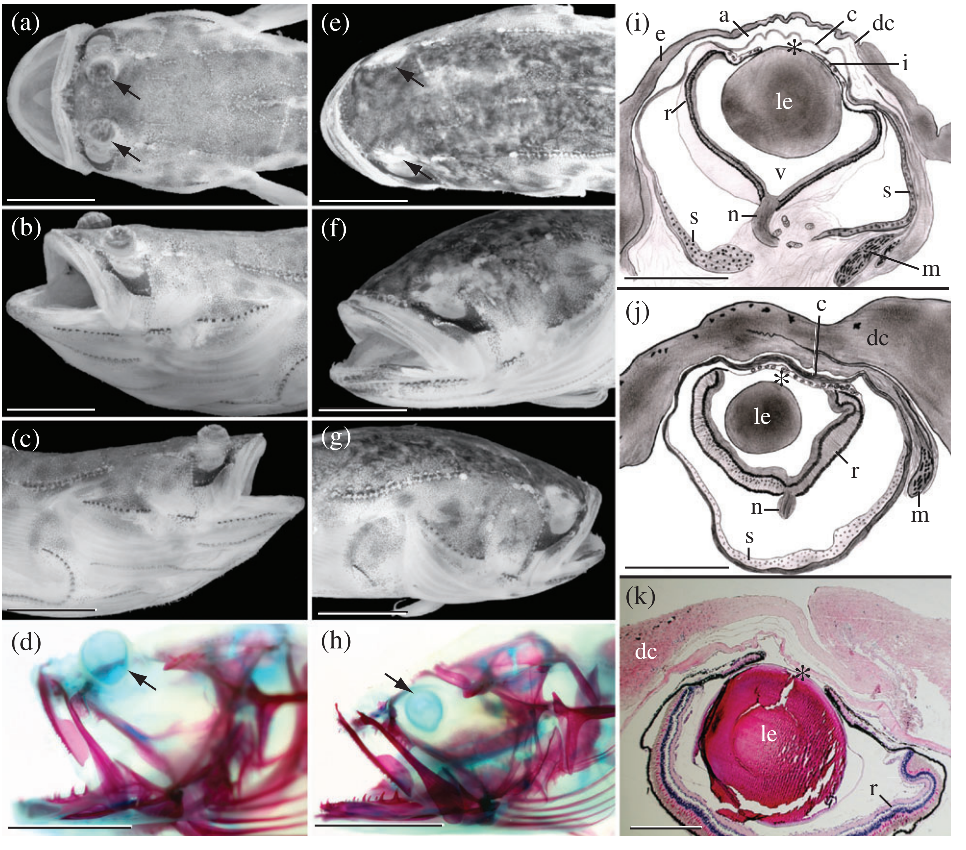

FIG. 1. *Porichthys plectrodon* from the Gulf of Mexico's outer continental shelf off Louisiana. (a–d) Normal specimen. (a) Dorsal view showing dorsal position of telescoped eyes (↑) and pigmentation of nape and dorsum. Scale bar = 10 mm. (b) Sinistrolateral view of specimen in (a). Scale bar = 10 mm. (c) Dextrolateral view of specimen in (a). Scale bar = 10 mm. (d) Sinistrolateral view of cranium showing pyriform globe (↑), alizarin-stained specimen from (a–c). Scale bar = 10 mm. (e–f). Anomalous specimen. (e) Dorsal view showing location of laterally directed eyestalk aperture (↑) and dorsal pigmentation. Scale bar = 10 mm. (f) Sinistrolateral view of specimen in (e). Scale bar = 10 mm. (g) Dextrolateral view of specimen in (e). Scale bar = 10 mm. (h) Sinistrolateral view of cranium showing semi-spheroid globe (↑), alizarin-stained specimen from (e–g). Scale bar = 10 mm. (i) Composite illustration of a series of serial histological sections selected at level of the pupil [*, eye facing dorsal (top of figure)], dextral aspect of specimen photographed in (a–d), showing epidermis (e), aqueous (a), cornea (c), dermal component of cornea (dc), iris (i), retina (r), lens (le), vitreous (v), sclera (s), optic nerve (n) and muscle (m). Scale bar = 1·25 mm. (j) Composite illustration of a series of serial histological sections selected at level of the pupil [*, eye 'facing' lateral (top of figure)], dextral aspect of specimen photographed in (e–h), showing thickened cornea (c), markedly thickened dermal component of cornea (dc), lens (le), retina (r), optic nerve (n), sclera (s) and muscle (m). Scale bar = 1·25 mm. (k) Histological section of eye showing position of pupil (*), lens (le), retina (r), extensive thickening of dermal component of cornea (dc) and diminished aperture. Scale bar = 1·0 mm.

The anomalous specimen [Fig. 1(e)–(h), (j), (k)] was immediately recognizable in the field by apparently lacking an external sign of an eye (appearing bilaterally anophthalmic), having a darkly pigmented nape and dorsum [Fig. 1(e)–(g)] and apparently lacking an eyestalk, eyestalk aperture and globe. Using stereomicroscopy of the whole specimen, the orbit was opaque and lacked extensive pigmentation, the eyestalk aperture was diminutive and the globe was recessed deeply within the cranium and overlaid by tegument [Fig. 1(e), (g), (j)]. As such, the pupil and orbit of the anomalous specimen resided on the lateral aspect of the head [Fig. 1(e), (h)], whereas the pupil and orbit reside more dorsally on the head in normal specimens [Fig. 1(a)–(d)]. The dorsal pigmentation of the head in the anomalous specimen was mottled, blotched and markedly less uniformly pigmented than that of normal specimens [Fig. 1(a), (e)].

Alizarin staining and clearing revealed that the anomalous specimen had a proportionally smaller globe (3·0 mm × 3·8 mm; greatest length perpendicular to long axis of body) that was spheroid in lateral profile, embedded within the cranium (*i.e.* not extending dorsally, concomitant with lack of an evident eyestalk) and, in lateral view, positioned below the level of the neurocranium [Fig. 1(h)]. The globe of normal specimens [3·8–5·0 (mean = 4·4) × 3·0–4·0 (mean = 3·7) mm] was pyriform in lateral profile and markedly telescoped dorsally (reaching above the level of the neurocranium surface) [Fig. 1(c), (d)]. In an attempt to better understand the interaction of the globe and eyestalk plus its aperture, and given that no live specimen was available for study, the globe of alizarin-stained, bisected, specimens was manipulated as a means of understanding how, and the extent to which, the eye articulates relative to the neurocranium. In normal specimens, the globe could be easily pushed inward such that it was nearly flush with the surface of the cranium; however, doing so did not produce a deeply sunken globe comparable with that observed in the anomalous specimen. In the anomalous specimen, the globe could not be forcibly pushed outward through the evidently diminished eyestalk aperture.

Histology of the anomalous specimen confirmed the presence of an intact eye [Fig. 1(i)–(k)] and indicated macroscopic changes associated with the cornea and eyestalk as well as seemingly minor cellular changes to the choroid rete. The cornea was markedly thickened and uneven [Fig. 1(k)], including melanin-like residue. The choroid rete occupied the area between the lens and cornea [Fig. 1(j)], and the dermal component of the cornea was markedly thickened, including eosinophilic fibrinous connective tissue [Fig. 1(j), (k)]. All specimens sectioned demonstrated a seemingly functional retina and sclera. No parasitic infection was detected grossly nor in a stained and cleared fish or histological section.

This case report cannot address aetiology of, nor the functional anatomical implications of, the putative ocular anomaly observed because the anomalous specimen was dead at capture. No other specimens were available for study, and only cursory information on the incidence of this apparent anomaly is available. Given that, it cannot be ruled out that the morphological anomaly described here does not represent intraspecific variation. Given the stark differences in the gross and microscopic anatomy of the globe, eyestalk and cornea, however, it is suggested that the anomaly observed indeed comprises a deviation from normal. It is also speculated that the difference in colouration to the head and nape of the anomalous specimen [Fig. 1(e)] may have resulted from ocular dysfunction related to its sunken eye and corresponding corneal thickening. This theoretically could affect the ability of the fish to sense light intensity.

Certainty in that regard is difficult because the available information shows that the literature lacks a treatment of the functional anatomy of the eyestalk of *P. plectrodon* or another batrachoidiform (Douglas *et al.*, 1998). Aside from phenotypic plasticity, some obvious possible aetiologies include barotrauma, infectious disease, wounding and non-infectious disease.

Barotrauma to the eye appears unlikely because (1) the eye was intact, cellularly complete, showing no indication of trauma; (2) the globe was sunken within the cranium (the pressure differential would force the eye out of the orbit rather than draw the eye towards the head); (3) the epithelium covering the globe was intact; (4) the thickened dermal component of the cornea was probably hyperplastic, indicating a chronic cellular process rather than an acute trauma; (4) no other classic sign of barotrauma was unobserved (abdomen and stomach not distended nor everted, respectively). Moreover, and most obviously, other specimens from depth had normal eyes, indicating that the trawl that netted these specimens of *P. plectrodon*, including the anomalous specimen, was retrieved slowly from depth. If the anomalous specimen was netted in shallow water and dragged deeper (causing pressure to collapse the eye), it is unlikely that the aqueous and vitreous humor would remain intact, in the observed confirmation [Fig. 1(h), (j), (k)].

Infectious disease also appears unlikely as a cause because no parasite was observed in the head of any fish or tissue section. No histological sign of bacterial infection was noted, but nor was any bacterial culture attempted. The possibility that the anomalous fish was scarred (as corneal thickening) from a previous, debilitating infection cannot be tested with the present data.

Wounding, another possibility, appears unlikely given that an intact eye was present and given that the anomaly was characterized by the apparent lack of an eyestalk, a globe that was sunken within the cranium, rather than protruding dorsally from it and a corresponding thickening of the dermal component of the cornea. The anomalous specimen was bilaterally symmetrical and lacked any sign of osteological disarray or asymmetry. A bite wound would probably result in osteological asymmetry or deformity; neither of which was observed.

Non-infectious disease, *e.g*. an ontogenetic disorder and toxicological response, cannot be assessed with the present materials but certainly warrants further investigation subsequent to additional spatial and temporal sampling of *P. plectrodon* in the north-central Gulf of Mexico. The results of the present work also underscore the need for deeper understanding of ontogenetic development, functional morphology and intraspecific variation in the anatomy of the eye of *P. plectrodon*.

The authors thank J. Davis, W. Wells and W. Wall (Venice, Louisiana, U.S.A.) for helping collect the anomalous *P. plectrodon* off Louisiana as well as C. Edds (Louisiana Department of Wildlife and Fisheries, Marine Fisheries Laboratory, Grand Isle, Louisiana, U.S.A.), J. Armbruster and D. Wernake (Auburn University Museum of Natural History), P. Chakrabarty [Louisiana State University Museum of Natural Sciences (LSU MNS), Baton Rouge, Louisiana, U.S.A.] and M. Grace and A. Hamilton (National Oceanographic and Atmospheric Administration, Southeast Fisheries Science Center, Pascagoula, Mississippi, U.S.A.) for providing access to vouchers of normal specimens of *P. plectrodon* from Gulf of Mexico localities. This is a contribution of the Center for Aquatic Surveillance and Health and Southeastern Cooperative Fish Parasite and Disease Project (Auburn University, School of Fisheries, Aquaculture, and Aquatic Sciences) and was supported in part by grants from the Gulf of Mexico Research Initiative and National Science Foundation.

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