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ONTOGENETIC DEVELOPMENT OF WEBERIAN OSSICLES IN THE BAGRID CATFISH, *PSEUDOBAGRUS ICHIKAWAI**

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The development of the Weberian ossicles and its related bones was described on the bagrid catfish, *Pseudobagrus ichikawai*, larvae and juveniles of 4.8–25.0 mm SL. The first appeared ossicles were cartilaginous basidorsals 4–6, at 6.5 mm SL, whereas the last appeared one was the cartilaginous claustrum at 10.2 mm SL. All the elements had almost completely ossified by 25.0 mm SL. The following results were obtained on the origin of the Weberian ossicles: the scaphium and intercalarium derived from the first and second basidorsals; and the tripus and os suspensorium originated from not only the third and fourth basiventrals but also from the third and fourth lateral processes, respectively.

Key words: *Pseudobagrus ichikawai*, Weberian ossicles, Ossification, Ontogenetic development

Introduction

The Weberian apparatus, composed of four or more anterior vertebrae and three or four small bony parts with ligaments, is an auditory apparatus unique to the ostariophysan fishes, including the cypriniforms, characiforms and siluriforms [Rosen and Greenwood (1970)]. Although the morphology of the Weberian apparatus has been studied well on adult fishes [Chardon (1968); Fink and Fink (1981); Chardon and Vandewalle (1991)], confusion still remains as to the origin and homology of some ossicles. To examine the ontogenetic development of the Weberian apparatus is a clue to solve such confusion, as pointed out by Vandewalle *et al.* (1990). Accordingly, there exists a need to continue collecting information on the development of the Weberian apparatus, despite the data already accumulated for some ostariophysans. The ontogenetic development of the Weberian apparatus in the cypriniforms has been described well by some researchers [see literature cited by Fukushima *et al.* (1992); Ichiyanagi *et al.* (1996)]. However, in the siluriforms, descriptions are limited to some species, *e.g.*, *Galeichthys felis* [Ariidae; Bamford (1948)], *Clarias gariepinus* [Clariidae; Radermaker *et al.* (1989)] and *Silurus asotus* [Siluridae; Ichiyanagi *et al.* (1993)]. The present study describes the ontogenetic development of the Weberian ossicles in the laboratory-reared and wild-caught bagrid catfish, *Pseudobagrus ichikawai.*

Materials and Methods

An ontogenetic series of *P. ichikawai* specimens ($N=29$, 4.8–10.2 mm SL), reared from 21 June to 16 July 1994 in the Laboratory of Ichthyology, Tokyo University of Fisheries, and deposited in the National Science Museum, Tokyo (NSMT-P 36087), was used for this study. Spawning and larval rearing were conducted in the same manner as those described by Watanabe (1994). Four wild-caught

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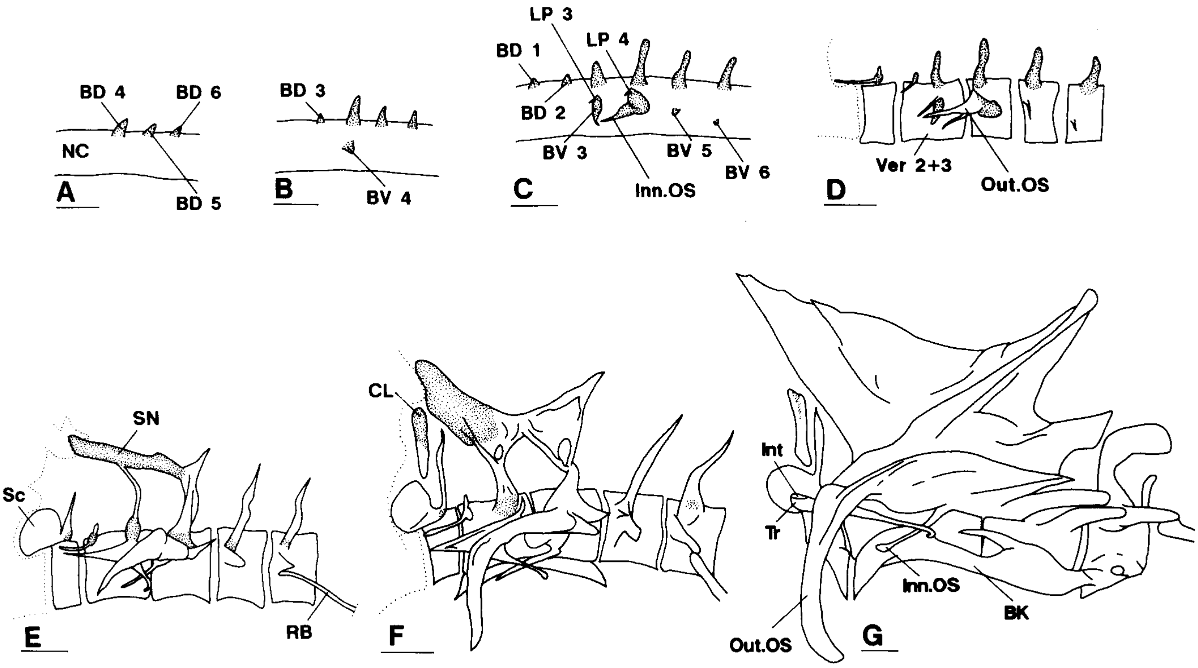

Fig. 1. Development of the Weberian ossicles in *Pseudobagrus ichikawai.* A) 6.5 mm SL; B) 6.8 mm SL; C) 8.3 mm SL; D) 8.4 mm SL; E) 9.1 mm SL; F) 10.2 mm SL; G) 24.8 mm SL. Cartilaginous portions are stippled, the dotted line indicating the skull. *BD 1–6*—basidorsals 1–6; *BK*—bony keel; *BV 3–6*—basiventrals 3–6; *CL*—claustrum; *Inn. OS*—inner arm of os suspensorium; *Int*—intercalarium; *LP 3,4*—lateral process 3,4; *NC*—Notochord; *Out. OS*—outer arm of os suspensorium; *RB*—rib; *Sc*—scaphium; *SN*—supraneural; *Tr*—tripus; *Ver*—vertebra. Scale bars: 0.2 mm.

young specimens (14.8 and 16.3 mm SL, NSMT-P 36106, collected from Kawaura River (Nagara River system), Gifu Prefecture, on 22 August 1992; 24.8 and 25.0 mm SL, NSMT-P 36107, collected from Kawaura River on 10 September 1991) were also examined. These specimens were cleared and stained following the method of Potthoff (1984), elements associated with vertebrae 1–6 being described in this study. Since *P. ichikawai* is an endangered species and designated as a "natural monument" for preservation purposes, collections of the specimens were conducted with the permission of the Japanese National Agency for Cultural Affairs.

Results

No Weberian elements were observed in 5.8 mm SL and smaller specimens, and all the elements had been completely ossified by the largest specimen examined, 25.0 mm SL.

A cartilaginous basidorsal, which grew later into the scaphium, was first observed at 8.3 mm SL (BD1 in Fig. 1C). A rod-shaped bone, anterior process, appeared from the lower part of basidorsal at 8.4 mm SL (Fig. 1D) and extended anteriorly thereafter. The cartilaginous base of basidorsal, articular process, disappeared at 8.4 mm SL, the scaphium being separated from the notochord (Fig. 1D). By 9.1 mm SL, the anterior process had expanded dorsally to form a bony plate, concha, which curving out slightly and being spoon-like in shape (Fig. 1E). A bony process projecting dorsally from the basidorsal, ascending process, appeared first at 9.1 mm SL (Fig. 1E) and then developed in size. The scaphium ossified completely at 14.8 mm SL (Fig. 1G: 24.8 mm SL).

A cartilaginous basidorsal, the intercalarium in further developmental stage, was first observed at 8.3 mm SL (BD2 in Fig. 1C). A rod-shaped bone, anterior process, had appeared by 8.4 mm SL (Fig.

1D) and extended anteriorly below and parallel to the concha of scaphium (Fig. 1E, F). The articular process disappeared at 8.4 mm SL (Fig. 1D). A small bony process, ascending process, had appeared by 9.1 mm SL (Fig. 1E), although not extended dorsally. The complete ossification of intercalarium was observed at 10.2 mm SL (Fig. 1F).

Posterior to the scaphium and intercalarium, the cartilaginous basidorsals 3 and 4–6, becoming the neural arches 3–6 later, appeared first at 6.8 (Fig. 1B) and 6.5 mm SL (Fig. 1A), respectively. A small rod-shaped bone had appeared and developed dorsally to the basidorsals 3–6 (Fig. 1E: 9.1 mm SL). A cartilaginous mass, which later developed into the supraneural, had appeared mid-dorsally to the anterior part of vertebrae by 9.1 mm SL, its ventral part having been fused with the rod-shaped bones 3 and 4 and ossifying (Fig. 1E). The cartilaginous basidorsal 4 was fused ventrally with the base of cartilaginous os suspensorium at 9.7 mm SL. Ossification of the supraneural and neural arches 3 and 4 had proceeded with growth (Fig. 1F, G).

No elements occurred on the ventral part of the first two vertebral columns in the specimens examined (Fig. 1).

A cartilaginous basiventral, which grew later into the tripus, was first observed at 6.8 mm SL (a different specimen from that drawn in Fig. 1B: BV3 in Fig. 1C). A laterally projected bone, lateral process 3, and a rod-shaped bone were observed on the dorsal base and tip of basiventral, respectively, at 8.3 mm SL (Fig. 1C). With larval growth, the lateral process had been fused with the ossifying basiventral, including the rod-shaped bone, and extended laterally and antero-posteriorly to form a triangular bony sheet by 9.1 mm SL (Fig. 1E). The posterior tip of tripus had increased in size, running between the inner and outer arms of the os suspensorium, and re-curved proximally to form a hook-shaped transformator process (Fig. 1E–G).

A cartilaginous basiventral, becoming os suspensorium in further developmental stage, appeared first at 6.8 mm SL (BV 4 in Fig. 1B). At 8.3 mm SL, a laterally projected bone, lateral process 4, was observed on the dorsal base of basiventral, and a rod-shaped bone, inner arm of os suspensorium, appeared at the tip of basiventral (Fig. 1C). The inner arm developed antero-ventrally in size, as larvae grew (Fig. 1D–G). The lateral process and ossifying dorsal base of basiventral had been fused with each other, projecting antero-laterally to form the outer arm of os suspensorium, by 8.4 mm SL (Fig. 1D). The outer arm developed along the dorsal surface of swimbladder and expanded antero-posteriorly to form a horizontal bony plate (Fig. 1E). The distal tip of outer arm turned downward, after the tip reached the antero-lateral edge of the swimbladder, and developed along the anterior surface of swimbladder (Fig. 1F, G).

Cartilaginous basiventrals 5 and 6, parapophyses 5 and 6 in further developmental stage, appeared first at 8.3 mm SL (BV 5 and 6 in Fig. 1C) and ossified at 8.4 mm SL (Fig. 1D). A rib attaching to the parapophysis of vertebra 6 appeared at 9.1 mm SL (Fig. 1E), whereas no paraphophyses being observed in the vertebrae 1–4.

A rectangular-shaped cartilage with ossifying part ventrally, claustrum, was first observed dorsally to the scaphium at 10.2 mm SL (Fig. 1F). The ossification proceeded dorsally and had been completed by 25.0 mm SL.

Separated vertebrae 1–6 were first observed at 8.1 mm SL, the vertebra 2 being much reduced in size compared with others (not appeared yet in the 8.3 mm SL specimen of Fig. 1C). Fusion occurred between vertebrae 2 and 3 at 8.4 mm SL (Fig. 1D) and between 2+3 and 4 at 10.2 mm SL (Fig. 1F), in the latter, a bony keel, running along the body axis, developing on both sides of the ventral part of vertebra 2+3+4 (Fig. 1F). The bony keel had appeared also on the ventral part of vertebra 1 by 24.8 mm SL (Fig. 1G), in which the vertebra 2+3+4 was fused with the vertebra 5, although not completely, and the bony keel extended to and was fused with the ventral part of vertebra 6 (Fig. 1G).

Discussion

As shown in this study, the tripus and os suspensorium of *Pseudobagrus ichikawai* originated from the basiventrals 3 and 4 and lateral processes 3 and 4, respectively. Radermaker *et al.* (1989) indicated a possibility of the os suspensorium to originate from the basiventral 4 and the rib, and Bamford (1948) suggested that the tripus and os suspensorium derived from the basiventrals 3 and 4 and each rib, respectively. However, the lateral processes 3 and 4 observed in the present study are considered to be different from ribs; the latter would develop freely from the vertebrae, whereas the former projected directly from the vertebrae. Ichiyanagi *et al.* (1993) reported no lateral process in the silurid catfish, *Silurus asotus*. However, based on our re-examination of their specimens (MTUF-P 26679) and some additional ones (MTUF-P(L) 101: $N=7$, 7.8–9.5 mm SL), the lateral processes 3 and 4 were observed in a 9.3 mm SL specimen.

Ichiyanagi *et al.* (1993) traced the ontogenetic development of intercalarium in *Silurus asotus*, the intercalarium originating from the basidorsal 2 and being separated into two ossicles, a free, small nodular one and a small spherical one. However, in this study, we could not observe the separated bony nodule in *Pseudobagrus ichikawai*.

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ネコギギのウェバー器官とその関連骨格の発達

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ネコギギ（体長 4.8〜25.0 mm, 33 個体）のウェバー器官を構成する骨片とその関連骨格の発達を記載した。最初に出現した構成骨は軟骨性の第 4〜6 底背で，体長 6.5 mm で出現した。一方，最後に出現したのは軟骨性の結骨で，体長 10.2 mm で最初に観察された。体長 25.0 mm の最大個体では，すべての構成骨がほぼ完全に化骨していた。本研究の結果，ネコギギのウェバー器官の構成骨の起源に関して，以下の知見が得られた：舟状骨と挿入骨は第 1，第 2 底背から各々発達した；三脚骨と Os suspensorium は，第 3，第 4 底腹に加えて，各々第 3，第 4 側突起からなることが判明した。

キーワード：ネコギギ，ウェバー器官，化骨形成過程，個体発生