Japanese Journal of Ichthyology
Vol. 38, No. 4 1992

魚類学雑誌
38巻4号 1992年

Ontogeny of the Caudal Skeleton in the Clariid Catfish *Clarias batrachus*

Kiyoshi Fujita
Tokyo University of Fisheries, 4-5-7,
Minato-ku, Tokyo 108, Japan

The caudal skeleton of siluriform fishes has already been studied by several authors, e.g. Whitehouse (1910), Merriman (1940), Hoedeman (1960), Tilak (1969), Lundberg and Baskin (1969), Singh and Jayaram (1981), Ayanomiya (1989), Kobayakawa (1989), for the purposes of classification and understanding of phylogenetic relationships. Among fishes of the genus *Clarias*, comparative morphology of the caudal skeleton has been studied in four species, viz. *C. lazera* (by Nawar, 1954), *C. angolensis*, *C. batrachus*, and *C. fuscus* (by Lundberg and Baskin, 1969) and *C. senegalensis* (by Monod, 1968). However, developmental osteology of these fishes was not covered in these papers.

The purpose of this study is to describe and comment on the development of the caudal skeleton of *Clarias batrachus*.

Materials and methods

The specimens of *Clarias batrachus* examined in this study were obtained from larvae which hatched in aquaria on 27 July, 1990, at the Laboratory of Ichthyology, Tokyo University of Fisheries. Incubating and rearing temperatures ranged from 24.5° to 31.5℃ (mean, 28.7℃). Larvae and juveniles were fed on *Artemia* nauplii and live *Daphnia*. About five specimens were sampled at one or two day intervals starting from hatching until the 25th day after hatching. They were preserved in 5% buffered formalin. A total of 135 specimens ranging from 3.6 mm in notochord length (NL) to 16.6 mm in standard length (SL) was used. Clearing and staining followed Dingerkus and Uhler (1977). Observations and illustrations were made by means of a dissecting microscope equipped with a camera lucida.

The terminology of the caudal skeleton follows Fujita (1990).

Results

The caudal complex of *Clarias batrachus* consists of one epural, one autogenous parhypural, five hypurals (the first and second hypurals are fused to each other at the proximal base), the first preural centrum +ural centrum 1+2 (PU1+U1+2) with pleurostyle, the long neural and hemal spines of the second preural centrum, and 14 branched caudal rays (7 in each lobe).

There were no caudal elements, except for the straight notochord, in larvae immediately after hatching (about 3.6 mm NL). Notochord flexion had occurred in some larvae from 4.6 to 4.9 mm NL, but no caudal elements were observed.

At 5.2 mm NL (Fig. 1A), 2 days after hatching, the second and third hypurals had been formed beneath the posterior notochord, which had started its flexion. There were two caudal rays extending backwards from the hypurals.

At 5.4 mm NL (Fig. 1B) the small, cartilaginous, fourth hypural was recognizable between the tip of the notochord and the third hypural. There were three rays in the upper caudal lobe and two in the lower lobe.

At 6.4 mm NL (Fig. 1C), a cartilaginous projection corresponding to the first hypural had formed at the base of the second hypural, and was elongated ventrally. The catilaginous parhypural was visible in front of the base of the fused hypural (HY1+2), and the number of caudal rays had increased to eight (four in each lobe).

At 7.2 mm NL (Fig. 1D) the small, cartilaginous, fifth hypural had been formed close to the tip of the notochord. There were five caudal rays in each lobe.

At 7.6 mm NL (Fig. 1E) the parhypural and the first to fifth hypurals had grown larger. Three cartilaginous hemal arches of future second to forth preural centra, were discernible at the ventral margin of the notochord, anterior to the parhypural. There were six rays in the upper lobe of the caudal fin, five in the lower.

At 8.7 mm SL (Fig. 1F) the epural was first seen, as a small cartilage above the notochord. Three cartilaginous neural arches of future third to fifth preural centra had been formed on the notochord, anterior to the epural. The parhypural and compound hypural (HY1+2) had become fused together at their proximal bases, and the tip of the parhypural, and the proximal bases of the middle part of HY1+2 and the third hypural had begun to ossify. There were seven rays in the upper lobe of the caudal fin, six in the lower.

At 9.4 mm SL (Fig. 1G) the ossified areas of the parhypural and the first to fourth hypurals had

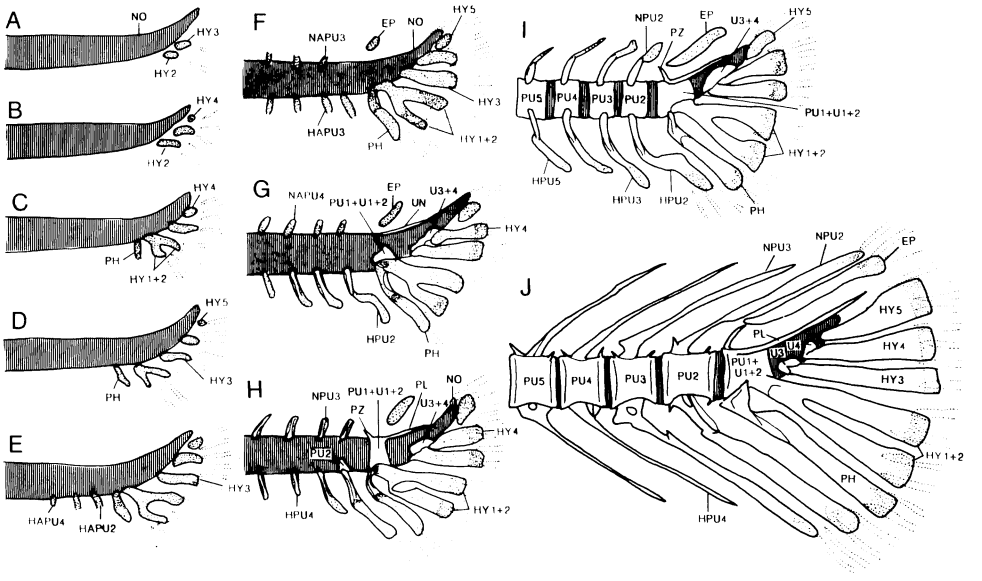

Fig. 1. Development of the caudal skeleton of *Clarias batrachus*. A: 5.2 mm NL. B: 5.4 mm NL. C: 6.4 mm NL. D: 7.2 mm NL. E: 7.6 mm NL. F: 8.7 mm SL. G: 9.4 mm SL. H: 9.7 mm SL. I: 11.2 mm SL. J: 16.6 mm SL. EP, epural; HY1+2, hypural 1 plus hypural 2; HY, hypural; HAPU, hemal arch of preural centrum; HPU, hemal spine of preural centrum; NAPU, neural arch of preural centrum; NPU, neural spine of preural centrum; NO, notochord; PH, parhypural; PL, pleurostyle; PU, preural centrum; PZ, prezygapophysis; U1, 2, 3, 4, ural centrum 1, 2, 3, 4; UN, uroneural. Dense dots indicate cartilage. Sparse dots indicate intermediate condition between cartilage and bone. Undotted areas indicate bone. Scale bars indicate 0.5 mm.

spread nearly to their distal ends. A pair of ossified uroneurals (UN) (probably compound uroneural) was visible for the first time, on the posterior notochord below the epural. The first preural centrum plus the ural centrum 1 + 2 (PU1 + U1 + 2) had appeared as ossified elements in the notochord and fused with the parhypural and compound hypural (HY1+2) at their proximal bases. A terminal compound ural centrum (U3+4) was visible in the notochord, fused with the third and fourth hypurals at their bases. Hemal spines of the preural centra were also visible. There were eight rays in the upper lobe of the caudal fin, seven in the lower.

At 9.7 mm SL (Fig. 1H) the uroneural and compound centrum (PU1+U1+2) had fused at the dorsal part of the centrum, forming the pleurostylar vertebra with prezygapophysis. The second preural centrum had appeared in the notochord and was fused with the hemal spine of the centrum at the proximal base. The neural arches and spines of the preural centra had begun to ossify. There were eight caudal rays in each lobe.

At 11.2 mm SL (Fig. 1I) the preural centra had been formed, and the neural spines grown longer. All elements of the caudal complex had increased in size and become almost completely ossified. The parhypural and compound hypural (HY1+2) were separated from each other at their proximal bases.

At 16.6 mm SL (Fig. 1J) the pleurostyle had enlarged and was extended above the center of the fifth hypural, along the dorsal side of the notochord. The terminal ural centrum (U3+4), which had fused with the third and fourth hypurals at their bases, had become divided into two centra (U3 and U4), which were reduced in size and would become indistinguishable from the hypurals in larger specimens.

Remarks

Lundberg and Baskin (1969) reported that in the

adults of the majority of catfishes, a reduced second ural centrum (=terminal ural centrum) fused with one or more hypurals lies in the cavity on the posterior face of the compound centrum (PU1+U1+2). In *Clarias batrachus* the terminal ural centrum (U3+4) is divided into two centra (U3 and U4), which become fused to the third and fourth hypurals during development.

One of the interesting phenomena in the development of the teleost caudal skeleton is the fusion and detachment of hypurals during the course of their development. In *Clarias batrachus*, the first hypural is formed as a cartilaginous projection at the base of the second hypural. The first and second hypurals (fused at the proximal bases) and the parhypural are first formed as autogenous cartilage, becoming fused together at their bases, but subsequently separating from each other as they ossify.

The developing pleurostylar vertebra of *Clarias batrachus* is formed by the fusion of the uroneural and the compound centra (PU1+U1+2). Many siluriform (Lundberg and Baskin, 1969) and cyprinid fishes (Fujita, 1990) have this type of pleurostylar vertebra. Many clupeid fishes have the pleurostylar vertebra fused to the uroneural and PU1 (Monod, 1968; Fujita, 1990).

Acknowledgments

I wish to express my gratitude to Professor Yasuhiko Taki, Tokyo University of Fisheries, for his valuable advice and critical reading of the manuscript. I am grateful to Dr. Kiyoshi Sakai, Tokyo University of Fisheries, for providing me with eggs of this species.

Literature cited

Ayanomiya, F. 1989. Morphological comparison of the Mekong giant catfish, *Pangasianodon gigas*, with other pangasiid species. Japan. J. Ichthyol., 36(1): 113–119.

Dingerkus, G. and L. D. Uhler. 1977. Enzyme clearing of alcian blue stained whole small vertebrates for demonstration of cartilage. Stain Technol., 52(4): 229–232.

Fujita, K. 1990. The caudal skeleton of teleostean fishes. Tokai Univ. Press, 897 pp., 2 plates. (In Japanese.)

Hoedeman, J. J. 1960. Studies on callichthyid fishes. 6. The axial skeleton of *Callichthys* and *Hoplosternum* (Pisces, Siluriformes). Bull. Aquat. Biol., 2(14): 37–44.

Kobayakawa, M. 1989. Systematic revision of the catfish genus *Silurus* with description of a new species from Thailand and Burma. Japan. J. Ichthyol., 36(2): 155–186.

Lundberg, J. G. and J. N. Baskin. 1969. The caudal skeleton of the catfishes, order Siluriformes. Amer. Mus. Nov., (2398): 1–49.

Merriman, D. 1940. Morphological and embryological studies on two species of marine catfish, *Bagre marinus* and *Galeichthys felis*. Zoologica, 25, part 2, (13): 221–248.

Monod, T. 1968. Le complexe urophore des poissons Téléostéens. Mem. Inst. Found. Afr. noire, Dakar, 81: 1–705.

Nawar, G. 1954. On the anatomy of *Clarias lazera*. J. Morphol., 94(3): 551–586.

Singh, R. and K. C. Jayaram. 1981. Utility of caudal fin ray counts in classification of supergeneric categories of Indian siluroid fishes. Bull. Zool. Surv. India, 4(2): 221–230.

Tilak, L. 1969. On the so-called second dorsal and second anal fins in a siluroid fishes (Pisces). Science and culture, 35(3): 114–116.

Whitehouse, R. H. 1910. The caudal fin of the Teleostomi. Proc. Zool. Soc. London (1910): 590–627, pl. 47–50.

(Received February 18, 1991; accepted August 15, 1991)

Clarias batrachus の尾部骨格の発達

藤田　清

1990年7月24日に東京水産大学で産卵した卵を孵化させ，その孵化仔魚を25日間飼育し，定期的に仔稚魚をホルマリン固定し，軟骨・硬骨二重染色法で尾部骨格の発達を調べた．

Lundberg and Baskin (1969) によれば，大多数のナマズ類の成魚では縮小した第2尾鰭椎 (=terminal centrum) が一つまたはそれ以上の下尾骨と癒合して，PU1+U1+2の後に存在するとしている．*Clarias batrachus* では terminal centrum は第3下尾骨 (HY3) と第4下尾骨 (HY4) の基部に癒合して出現する．発達の過程で terminal centrum は下尾骨に癒合したまま尾鰭椎3 (U3) と尾鰭椎4 (U4) に二分され，そのまま縮小してそれぞれの下尾骨と区別がつかなくなる．側尾棒骨をそなえる脊椎骨は尾神経骨と尾鰭椎前第1椎体＋尾鰭椎 (PU1+U1+U2) との癒合によって形成された．

(108 東京都港区港南4-5-7　東京水産大学)