Japan. J. Ichthyol.
41(3): 334-337, 1994

魚類学雑誌
41(3): 334-337, 1994

Development of the Caudal Skeleton in the Saury, *Cololabis saira*

Kiyoshi Fujita[1] and Yoshioki Oozeki[2]

[1] Laboratory of Ichthyology, Tokyo University of Fisheries
4-5-7 Konan, Minato-ku, Tokyo 108, Japan
[2] Tohoku National Fisheries Research Institute
3-27-5 Shinhama-cho, Shiogama, Miyagi 985, Japan

(Received April 1, 1994; in revised form September 13, 1994; accepted October 14, 1994)

Previous studis on the caudal skeleton of the scomberesocid fish, *Cololabis saira* by Chapman (1943), Monod (1968) and Fujita (1990), only briefly described and figured the bony elements of the caudal skeletal complex. This study describes and comments on the development of that complex.

Material and Methods

The specimens of *Cololabis saira* examined in the present study were collected by the research vessel Soyo-maru in Pacific coastal waters off Kii to Boso Peninsulas, Honshu, Japan, between the 24th of February and 22nd of March, 1988. All of the specimens were caught by surface net (1.3 m in diameter, 2 mm and 335 μm mesh) tow and fixed in 5% formalin-seawater. Following the method of Dingerkus and Uhler (1977), a total of 307 specimens ranging from 5.5 mm to 65.0 mm SL were stained for bone with alizarin red S, for cartilage with alcian blue 8 GX, and then cleared with enzyme solution. Observations and illustrations were made under a dissecting microscope equipped with a camera lucida.

Caudal skeleton terminology follows Fujita (1990).

Results

The caudal complex of *Cololabis saira* consists of two epurals, two hypural plates (upper one, probably corresponding to fused third and fourth hypurals, and lower one, parhypural with hypurapophysis fused with first and second hypurals; upper hypural plate being autogenous, and lower one fused with the urostyle at the proximal base), probably a compound uroneural and fifth hypural, a short neural arch of the second preural centrum, long hemal spines of the third and fourth preural centra fused with each centrum at the proximal base, and 29 caudal rays (14, upper; 15, lower) (see Fujita, 1990).

At 5.5 mm SL (Fig. 1A), the smallest specimen collected, notochord flexion had already occurred, and beneath its posterior portion, a cartilaginous parhypural (PH) and two hypural plates were present. The slit-like line at the middle of the upper hypural plate probably indicated the point of fusion of the third and fourth hypurals. Laterally paired uroneurals (UN) had formed just dorsally to the posterior tip of the flexed notochord. Four caudal fin rays extended from each of the two hypural plates.

At 6.3 mm SL (Fig. 1B), the urostyle (US) had formed at the posterior end of the notochord, and fused to the proximal bases of the parhypural and compound hypural (HY1+2). A cartilaginous fifth hypural (HY5) was present above the upper compound hypural (HY3+4). Cartilaginous neural arches of the future third and preceding preural centra had formed. Cartilaginous hemal spines of the second and third preural centra, and the hemal arches of the preceding centra had appeared. There were six rays in the caudal fin upper lobe and seven in the lower.

At 7.5 mm SL (Fig. 1C), the second epural (EP2) had appeared as a cartilaginous element just above the uroneural. A cartilaginous neural arch of the future second preural centrum (NAPU2) was present, and the proximal parts of the hemal spine of the second preural centrum (HPU2), the parhypural and the hypural plates had begun to ossify. Seven upper, and eight lower caudal fin rays were visible.

At 8.5 mm SL (Fig. 1D), the preural centra (PU2 and anterior ones) had formed, the now fused associated neural and hemal spines had begun to ossify proximally, and the second neural element (NPU2) had elongated to about twice the longth of the third preural centrum. The hypurapophysis (PP) was a small appendage at the proximal base of the parhypural.

At 9.3 mm SL (Fig. 1E), the preural centra were larger than those of the previous stage, and all components of the caudal skeleton, except the second epural (EP2) and neural spine of PU2, had almost ossified. There were eight rays in both the upper and lower lobes of the caudal fin.

At 10.5 mm SL (Fig. 1F), a short cartilaginous third epural (EP3) had formed behind EP2. The long neural spine of PU2 exhibited a constriction at the top of the neural arch. The hypurapophysis (PP)

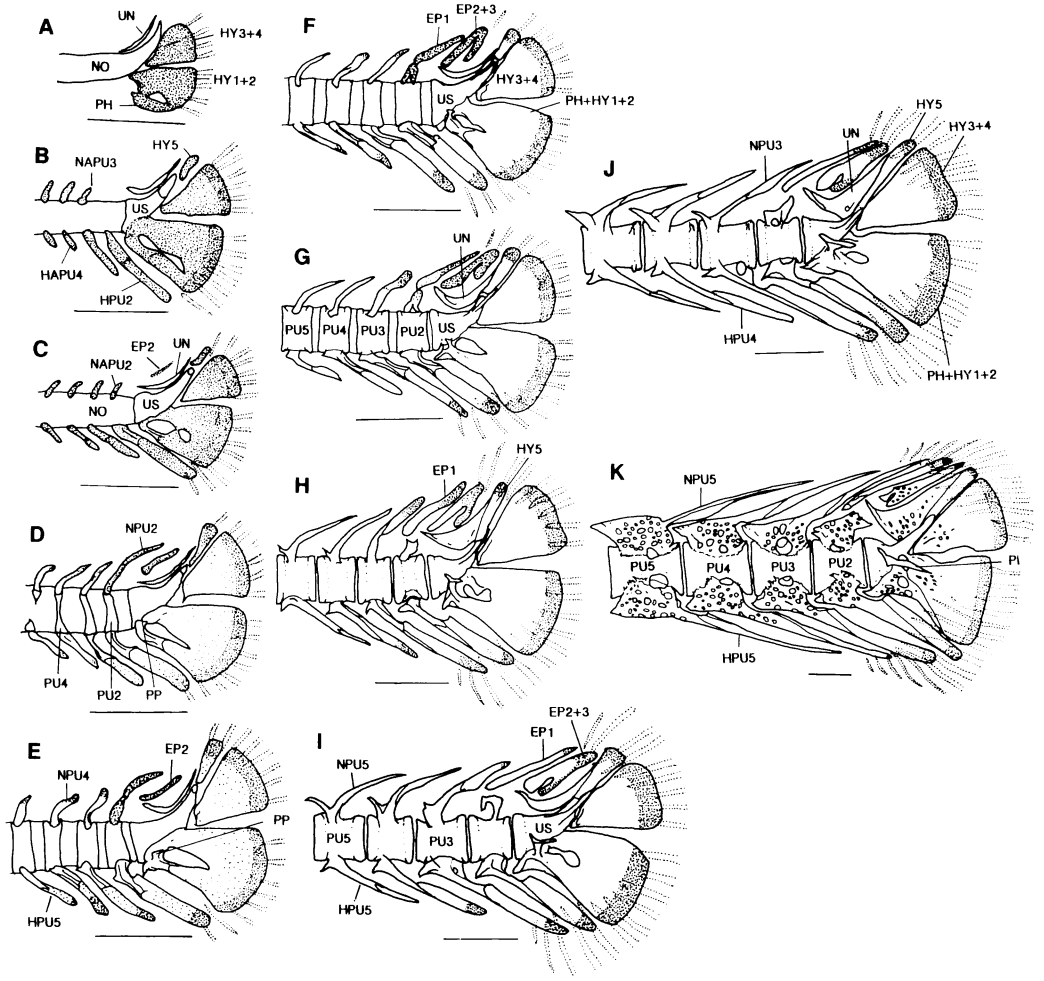

Fig. 1. Development of the caudal skeleton of *Cololabis saira.* A) 5.5 mm SL; B) 6.3 mm SL; C) 7.5 mm SL; D) 8.5 mm SL; E) 9.3 mm SL; F) 10.5 mm SL; G) 12.0 mm SL; H) 13.5 mm SL; I) 15.0 mm SL; J) 17.5 mm SL; K) 31.5 mm SL. *EP*—epural; *HY*—hypural; *HAPU*—hemal arch of preural centrum; *HPU*—hemal spine of preural centrum; *NAPU*—neural arch of preural centrum; *NPU*—neural spine of preural centrum; *NO*—notochord; *PH*—parhypural; *PP*—hypurapophysis; *PU*—preural centrum; *UN*—uroneural; *US*—urostyle. Dense dots indicate cartilage; sparse dots, areas intermediate between cartilage and bone; and clear areas (except notochord) bone. Scale bar indicates 0.5 mm.

had become a prominent process at the proximal base of the parhypural. Eight and nine rays were now present in the upper and lower caudal fin lobes, respectively.

At 12.0 mm SL (Fig. 1G), all components of the caudal skeleton were larger than those of the previous stage, and an enlarged uroneural (UN) had fused posteriorly with the fifth hypural. The first epural (EP1), which had begun ossifying proximally, had separated from the neural arch of PU2, and the distal fusion between the cartilaginous second and third epurals had developed greatly. One additional ray had formed on both the upper and lower caudal fin lobes, bringing the total figures to 9 and 10, respectively.

At 13.5 mm SL (Fig. 1H), the first epural (EP1) had completely separated from the neural arch of PU2, and the compound element formed by the fusion of the uronural and fifth hypural (HY5) was further fused with the flexed posterior tip of the urostyle. The compound epural (EP2+3) had begun to ossify at its antero-proximal tip. Nine

(upper) and eleven (lower) rays were present in the caudal fin lobes.

At 15.0 mm SL (Fig. 1I), all elements of the caudal complex had almost completely ossified. The compound epural (EP2+3) had become a thick bone, retaining only a vestige of the fusion at its biarmed proximal base.

At 17.5 mm SL (Fig. 1J), ten (upper) and eleven (lower) rays were present in the caudal fin lobes. The full complement of 29 caudal rays (14 upper, and 15 lower) was found in specimens larger than 31.5 mm SL (Fig. 1K). A greatly enlarged hypurapophysis (PP) was also observed.

Remarks

In adult *Cololabis saira*, two hypural plates (upper and lower) are present, the upper one being formed by the fusion of the third and fourth hypurals, and the lower one, by fusion of the parhypural with a compound first and second hypural (HY1+2) during early ontogeny. What appears in adults as an enlarged uroneural is actually a compound uroneural-fifth hypural formed by the fusion of these two independently-derived elements. Many belonids (see Collette, 1966; Monod, 1968; Fujita, 1990), exocoetids (see Rosen, 1964; Monod, 1968; Chen and Shen, 1978; Fujita, 1990), hemiramphids (see Monod, 1968; Fujita, 1990) and scomberesocids (see Monod, 1968; Fujita, 1990) also have a pair of enlarged uroneurals above the urostyle, indicating a shared caudal skeletal character among these families.

In adult *Cololabis saira*, two epurals are present. Monod's (1968) figure and description of the caudal skeleton indicated one epural, but his specimen may have been aberrant, because all specimens observed in this study had two epurals. The anterior epural (EP1) was derived by separation of the distal portion of the neural spine of PU2. Previously (see Fujita, 1990: fig. 161, p. 342), the posterior one was identified as EP2, but this study showed that it is actually a compound element (EP2+3) formed by the fusion of the second and third epurals, a vestige of this fusion being retained in the biarmed proximal base. Most beloniform fishes have three epurals. As there are two in the scomberesocid *Cololabis saira* (see Fujita, 1990), the belonid *Belone bellone* (see Monod, 1968) and the adrianichthyid *Oryzias* (see Rosen, 1964; Parenti, 1981; Iwamatsu and Hirata, 1980; Yabumoto and Uyeno, 1984; Fujita, 1990), and 1–2 in the adrianichthyid *Xenopoecilus* (see Rosen, 1964), the ontogenetic fusion shown in this study suggests that the decrease in number of epurals may be a derived caudal skeletal character in the beloniform fishes.

Acknowledgments

We are grateful to Dr. Kazunori Kuroda, Tohoku National Fisheries Research Institute, for encouraging this study. We wish to express our thanks to the captain and crews of R/V Soyo-maru for collecting the specimens.

Literature Cited

Chapman, W. M. 1943. The osteology of the Pacific saury, *Cololabis saira*. Copeia, 1943: 171–182.

Chen, C.- H. and S.- C. Shen. 1978. Taxonomical studies on the flying fishes (Oxyporhamphidae and Exocoetidae) from the waters around Taiwan. Ins. Oceanograph. Coll. Chinese Culture: i–iii+1–182.

Collette, B. B. 1966. *Belonion*, a new genus of fresh-water needlefishes from South America. Amer. Mus. Novt., (2274): 1–22.

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

Fujita, K. 1990. The caudal skeleton of teleostean fishes. Tokai Univ. Press, Tokyo. 897 pp., 523 figs., 2 pls.

Iwamatsu, T. and K. Hirata. 1980. Comparative morphology of three species of the genus *Oryzias*. Bull. Aichi Univ. Edu., Nat. Sci., 29: 103–120.

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

Parenti, L. R. 1981. A phylogenetic and biogeographic analysis of cyprinodontiform fishes (Teleostei, Atherinomorpha). Bull. Am. Mus. Nat. Hist., 168, Art. 4: 335–557.

Rosen, D. E. 1964. The relationships and taxonomic position of the halfbeaks, killifishes, silversides, and their relatives. Bull. Am. Mus. Nat. Hist., 127: 217–268.

Yabumoto, Y. and T. Uyeno. 1984. Osteology of the rice fish, *Oryzias latipes*. Bull. Kitakyushu Mus. Nat. Hist., 5: 143–161.

サンマの尾部骨格の発達

藤田　清・大関芳沖

紀伊半島沖から房総半島沖の海域で表層ネットによって採集したサンマの仔稚魚307尾（体長5.5–65.0 mm）の標本に基づき，尾部骨格の発達を調べた．

最小の体長 5.5 mm の個体ですでに脊索の上屈が完了し，尾神経骨，準下尾骨，上・下葉の下尾骨が出現し，体長 10.5 mm の個体で尾鰭条を除く尾部骨格がほぼ形成されていた．サンマの成魚は 2 本の上尾骨を備えるが，発達過程において第 1 上尾骨 (EP1) は尾鰭椎前第 2 椎体の神経棘 (NPU2) が神経弓門から分離してでき，第 2 上尾骨は 2 本の上尾骨 (EP2 と EP3) が癒合して 1 本となり，形成されることが明らかとなった．上尾骨のこのような形成過程と多くのダツ目魚類が 3 本の上尾骨をもつことから判断して，数の減少した上尾骨は派生形質と考えられた．

(藤田：〒108 東京都港区港南 4-5-7　東京水産大学魚類学研究室；大関：〒985 宮城県塩釜市新浜町 3-27-5　東北区水産研究所)