Osteological Annotations on the Skull of the
Landlocked "Ayu", Plecoglossus altivelis

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The osteology and relationships of the salmonoid fish, Plecoglossus altivelis T. & S., have been treated in detail by Chapman (1941). However, during the course of morphological studies of the landlocked form of this species, some doubts arose concerning certain osteological features described by him. It seemed desirable, therefore, to repeat a discussion of the skull.

The present study is based upon twelve landlocked specimens from Lake Biwa, measuring 40.0-71.5 mm. in standard length. In order to examine the racial variation, six additional collections of young marine form were made from Ise Bay. The skeletons were cleared and stained by the technique devised by Hollister (1934).

In general, with growth of the fish there is a gradual increment in the extent of calcification of all skeletal elements in this species. The skull of the landlocked form does not attain complete ossification and, in consequence, some elements of this organ are articulated with an intervening rather broad cartilaginous patch.

Cranium (Fig. 1, A and B): In general physiognomy of the cranium the present specimens agree in description with that presented by Chapman (1941). In dorsal view the mesethmoid appears as a flat shield, rounded anteriorly. The frontals, covering most of the top of the cranium, are separated from each other for their entire length and the anterior halves are especially widely separated. The bone bears a sensory canal ending vertically above the prefrontal. The posterior extension of the frontal overlies the broad parietal, and the lateral projection conjoins with the anterior half of the sphenotic. The parietal is a thin, broad bone of nearly trapezoid shape. The single median supraoccipital is surrounded by parietals, epiotics, and exoccipitals. Its small mesial crest is elevated on the dorso-posterior surface. Only a small dorsal surface of the exoccipital is exposed behind the supraoccipital. The epiotic articulates with the supraoccipital, exoccipital and pterotic, so that it forms the dorso-posterior corner of the cranium. Each pterotic is fused with the sphenotic and parietal at the dorso-anterior extremity, but laterally it is widely separated from the parietal by an intervening broad cartilaginous patch.

In the lateral view, the vomer occupies the ventro-anterior corner of the cranium. No tooth is recognizable on the vomer. There is a large fenestella between the ethmoid cartilage and the mesethmoid. The parasphenoid is a single, elongated bone

Received March 10, 1955.
extending along almost the entire midline of the ventral surface of the cranium. It expands and sends a short wing to ahead of the prootic, to cartilaginous band between prootic and basioccipital, and to postero-ventral area of basioccipital respectively. The alisphenoid is covered by the ventral flange of the frontal; the posterior extension of this bone articulates with the sphenotic dorso-posteriorly and with the prootic ventro-posteriorly. The lateral side of the brain case is composed of four skeletal elements, that is, prootic, opisthotic, exoccipital and basioccipital. There is a fenestella on each lateral surface of the prootic and exoccipital, the first being a passage for the trigemino-facial complex and the second is for the vagus nerve.

The most striking features of the Plecoglossus cranium are the lack of both a basisphenoid and an orbitosphenoid.

**Suspensorium and Opercular Apparatus (Fig. 2, A and C):** The hyomandibular, a flat wedge in shape, is the key suspensorium of the lateral facial bone. The wide upper margin articulates with the ventro-anterior surface of the pterotic and the lateral process of the sphenotic. The lower lateral edge of the bone is covered by the flat quadrangular metapterygoid, and the posterior extension is in contact with the preopercle. The symplectic is a rod-shaped bone, the lower end of which fits into a notch of the quadrate. Roughly speaking, the quadrate is fan-like in shape and bears a deep notch on the dorsal edge. The base of the bone is slightly thickened and is ankylosed with the articular. The mesopterygoid is a broad, thin
laminar plate forming the main portion of the floor for the orbit. The ventral surface is armed with twelve minute conical teeth in a single series. The pterygoid is a narrow bar suspended under the ventral surface of the mesopterygoid. The palatine is a short rod bearing three cartilaginous condyles, two of which are located on the anterior edge and the other at the posterior end. It bears no teeth. There is a cartilaginous patch between the palatine and the mesopterygoid, and it articulates with ventro-anterior end of the prefrontal.

Fig. 2. Lateral aspects of the suspensorium, opercular apparatus and jaws of Plecoglossus altivelis T. & S. (A), from a young marine specimen measuring 38.5 mm. in standard length. (B) and (C), from a landlocked specimen measuring 65.5 mm. in standard length. AN. angular; AR. articular; CT. comb like teeth; D. dentary; HM. hyomandibular; IO. interopercle; M. maxillary; MSP. mesopterygoid; MTP. metapterygoid; O. opercle; PL. palatine; PG. pterygoid; PM. premaxillary; POP. preopercle; Q. quadrate; S. symplectic; SM. supramaxillary; SOP. subopercle. Each scale indicates 3 mm.

All four opercular elements are present and well developed. The posterior three elements, the opercle, subopercle, and interopercle are imbricated. The preopercle is a large crescentric bone. The anterior margin of the upright limb rests on the posterior edge of the hyomandibular and the lower limb extends forward as far as the suspensory angle of the mandible. The sensory canal of the bone bears four prominent openings.

The young specimens are provided with all skeletal elements, though the ossification is little progressed (Fig. 2 A). The flat interopercle is situated under the preopercle in this stage.
**Jaws** (Fig. 2 A, B and C): The upper jaw is formed by the maxillary, premaxillary and supramaxillary. Chapman (1941) said nothing of the supramaxillary in *Plecoglossus*. However, the splint-like supramaxillary rests on the dorso-posterior edge of the large maxillary in both landlocked and marine forms. Since the bone is strongly affiliated with the maxillary, it is scarcely recognizable without staining. The spatula-like maxillary articulates with the palatine by the nodule which rests on the dorso-anterior tip of the former. The small premaxillary, which forms the tip of the snout, is joined for its entire length to the maxillary. Neither the premaxillary nor the maxillary bear teeth directly.

The lower jaw is made up of the dentary, articular and angular. The anterior edge of large dentary meets its counterpart of the opposite side at the symphysis. The incised portion of the dentary is conjoined with both upper and lower edge of the articular. The bone of the landlocked form bears four small conical teeth directly. The articular is a slender bone articulating with the quadrate at the dorso-posterior edge. The angular is a small triangular bone firmly fused with the articular.

The peculiar comb-like teeth, which appear to be developed as an adaptation to the feeding habits of the fish, are arranged obliquely on the jaws of the adult fish. The comb-like plate is not attached to the maxillary or dentary directly, but is rooted in the tough connective tissue layer. Usually, ten to fourteen such plates are set on each jaw. Young specimens, measuring less than about 55 mm. in standard length, do not bear such peculiar dentition, as was pointed out by Matsui (1938).

Remarks: The present investigation demonstrates the presence of a typical supramaxillary which was overlooked by Chapman. Likewise, though it is not concerned with osteological features, in *Plecoglossus* a pair of ovaries is developed asymmetrically, whereas Chapman stated that there is only a single ovary in this species. These two additional facts, as well as the curious adherent mechanism of the fertilized eggs in both *Plecoglossus* and *Hypomus*, which was confirmed by Kanoh (1952), emphasize Chapman's final conclusion that *Plecoglossus* is more closely related to the osmerid fishes than to the other salmonoids.

Moreover, in evaluating the results of these dissections, an attention should be called to the incomplete ossifications in the mature landlocked *Plecoglossus*. From this evidence, it is readily seen that this form is remained in the status of inadequacy not only in the growth of fish but in the ossifications of the skeletal elements. A fertile field of investigation is thus opened for future study.

I wish to express my gratitude to Professor K. Matsubara for his cordial guidance enabling me to complete this article.

**References**


