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Development of the Neurocranium in *Micropogonias furnieri* (Perciformes: Sciaenidae)

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Abstract The osteological development of the neurocranium of *Micropogonias furnieri* (Perciformes, Sciaenidae) is described with special attention to the substitution of cartilage by bone. Preflexion, flexion, postflexion larvae and juveniles from 3.8 mm NL to 48.3 mm NL and adult of 380 mm SL were cleared and stained. The preflexion larvae, 3.8 mm NL to 4.2 mm NL, present a completely chondrified neurocranium. In the flexion larvae from 5.8 mm NL to 7.8 mm NL the frontal and supraoccipital are present as a transparent lamina and the ethmoidal and otic regions are chondrified. In the postflexion larvae around 8.0 mm SL to 14.0 mm SL, a number of ossification areas are observed such as the supraorbital ridge of the frontal, the supraoccipital and supraoccipital crest, the parietal, the parasphenoid, part of the exoccipitals and the wall of the trigeminofacialis chamber. In the juveniles of approximately 14.0 mm SL to 48.3 mm SL major ossification is at the ethmoid, orbital and otic regions, the ethmoid being the most ossified region. The vomer and the prefrontal are less ossified; the frontal is partially ossified but with incomplete or absent ridges. The parietal, the occipital and supraoccipital ridge ossify rapidly. The otic capsule ossifies more slowly, presenting a large cartilaginous area at 48.3 mm SL. The parasphenoid and basioccipital have got a large ossified extension since 14.0 mm SL. In the adult of 380 mm SL all the regions are completly ossified. The supratemporal suture with the pterotic is not distinguished; these structures fuse very early in the development process.

Several papers on the growth, development characteristics and taxonomy of Sciaenidae larvae have been written (Hildebrand, 1934; Joseph, 1962; Joseph et al., 1964; Johnson, 1978; Powles and Stender, 1978; Powles, 1980; Sinque, 1980; Moser et al., 1983). Studies on the biology and life cycle of *Micropogonias furnieri* (Desmarest, 1823) from the West Atlantic were performed by Vazzoler (1969, 1971) and Vazzoler et al. (1973). Regarding the osteological development of the branchiocranium, post cranial and appendicular skeleton and digestive tube of this species, a study was made by Weiss (pers. comm.). The adult cranium was described by Gregory (1933). However, no work is known on cranial development, especially as regards the neurocranium. In the adult Perciformes, in general, and, especially in *Menticirrhus*, *Umbrina*, *Pogonias*, *Stellifer*, *Paralonchurus* species the neurocranium presents fused bones, mainly of the intertemporal-supratemporal complex according to Topp and Cole (1968). Therefore we attempted to document the osteological development of the neurocranium, for the purpose of finding out at which stage and how fast this fusion occurs, using specimens collected in Southeast Brazil.

Materials and Methods

This paper is based on the study of 60 specimens collected in the Patos lagoon estuary located near the city of Rio Grande, Rio Grande do Sul, Brazil. The pre and post notochordal flexion larvae were collected using plankton nets (0.5 mm between knots) and juveniles with otter trawl nets (12.0 mm between knots) at latitude 32°02′S and longitude 52°05′W.

The larvae were fixed in 4% formaldehyde, buffered with sodium borate and juveniles in 4% formaldehyde. Some of the larvae were provided and identified by Dr. Graciela Weiss of the Ichthyoplankton Laboratory of the Fundação Universidade de Rio Grande (FURG), Rio Grande do Sul, Brazil. All specimens have been deposited in the collection of the Ichthyology Laboratory of the Department of

Zoology, Universidade Federal do Rio Grande do Sul (UFRGS).

The series of 60 specimens were cleared and stained after Dingerkus and Uhler (1977), the preflexion and flexion larvae stained blue all over, making it difficult to identify bone units.

The specimens were measured using stereomicroscope with micrometer. The body length of preflexion and flexion larvae were measured from the anterior tip of the upper mandible to the posterior end of notochord (notochord length, NL), and for the postflexion larvae and juveniles, standard length (SL) were measured. The specimens were described in 100% liquid glycerin. The drawings were made with camera lucida attached to a stereomicroscope in which the dotted regions indicate cartilage and the clear spaces are bone.

In each stage, neurocranium ossification was described by dividing into four regions such as: ethmoid, orbital, otic, and basicranial.

The stages of development were defined according to Kendall et al. (1984). The osteological terms used follow de Beer (1937) and Jardim (1988). The osteological term intertemporal-supratemporal used follows de Beer (1937), Topp and Cole (1968) and Jollie (1975). The same bone is refered to as dermopterotic by Patterson (1977) and as supratemporal by Parrington (1967) and Weisel (1967). Furthermore, in the description sequence, the omission of bones or cranial regions means that they are completely ossified.

Description

3.8 mm NL larva.—This smallest specimen is preflexion larva with cranial stress areas (maxillomandibular apparatus and branchial arches). The cartilaginous bars on the brain floor are joined to each other, forming the trabecula communis, and later join the cartilaginous plate which constitutes the otic capsule and envelops the anterior portion of the notochord (Fig. 1A). In its anterior part, the trabecula communis is joined to the ethmoid plate. The orbital cartilage or taenia marginalis goes from the ethmoid plate to the lateral commissure, which includes the anterior lateral margin of the otic capsule, and passes over the eyes. The otic capsule presents in the form of two triangular fenestrated plaques (basicranial fenestrations), and lies on the medioventral line, enveloping the notochord (Fig. 1A). The opposing taenia marginalis are linked, to halfway through their length by a bar called epiphyseal bar, which corresponds to the future anterior roof of the cranial cavity. In the otic capsule can be observed the septa for the semicircular canals which may be distinguished due to their opacity in relation to the remainder of the capsule. From the lateral tips of the ethmoid plate, on each side, comes pillar-shaped cartilage, the orbitonasal lamina, which proceeds towards the orbital cartilage. Ascending from the center and anteriorly to the ethmoid plate rises a pillar called nasal septum. The orbital cartilage is fused on one side to the nasal septum and on the other to the orbitonasal lamina, delimiting the olfactory foramen advehens (Fig. 1A). This structure is the future roof of the nasal capsule.

6.8 mm NL larva.—It presents notochordal flexion and a better defined neurocranium, with an occipital arch formed by cartilage. Two centers of the dermal ossification are visible. One in the area of the frontal bone and one in the parasphenoid area (Fig. 1B). At the ethmoid region the ethmoid plate, the nasal septum and the tectum cranii are still cartilaginous and are dorsally interconnected (Fig. 2A). The ethmoid plate extends backwards, ventrally, through the trabecula communis. The orbital region shows signs of formation of the frontal bony plate and early stages of orbital cartilage (Figs. 1B, 2A, 3A). In otic region, the superior occipital cartilage, the lateral commissure and early stages of the auditory capsule are developed. The septa to the lateral and posterior semicircular canals are developed. In basicranial region early stages of the parasphenoid are defined. Notochord is also present (Fig. 3A).

9.0 mm SL larva.—In this postflexion larva the ethmoid region is better defined and the growth and fusion of the orbital cartilage with the ethmoid plate are perceived (Fig. 1C). The trabecula communis and nasal septum are still clear. At the orbital region there is a reduction of orbital cartilage, with formation of the frontal bony edges (Figs. 1C, 2B). At the otic region the lateral edge of the neurocranium is marked by the bony edges of the intertemporal-supratemporal. The auditory bulla stands out, though is still cartilaginous (Fig. 3B). The occipital arch formation is cleary observed with a small supraoccipital crest. In the basicranial region, the cartilage is still present.

13.1 mm SL larva.—In this postflexion larva the neurocranium also presents chondrification of most structures. The ethmoid region is completely carti-

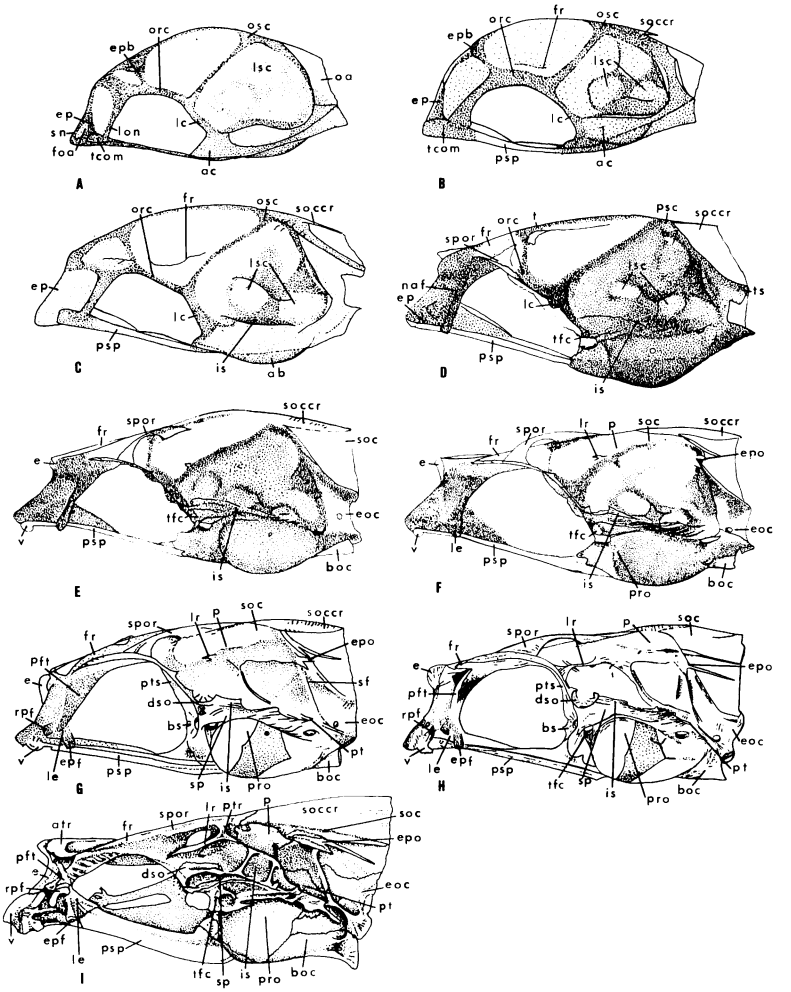

Fig. 1. Lateral view of larval and juvenile neurocranium of *Micropogonias furnieri*. The cartilaginous basal is ticked with dotted points and the bones are the clear spaces. A) Preflexion larva, 3.8 mm NL; B) flexion larva, 6.8 mm NL; C) postflexion larva, 9.0 mm SL; D) postflexion larva, 13.1 mm SL; E) juvenile, 17.4 mm SL; F) juvenile, 23.7 mm SL; G) juvenile, 31.5 mm SL; H) juvenile, 48.3 mm SL; I) adult, 380 mm SL. *ab*—acoustic bulla; *ac*—auditory capsule; *atr*—anterior transverse ridge; *boc*—basioccipital; *bs*—basisphenoid; *dso*—dermosphenotic; *e*—ethmoid; *ep*—ethmoid plate; *eoc*—exoccipital; *epb*—epiphysial bar; *epf*—ethmopalatine facet; *epo*—epiotic; *foa*—foramen olfactorium advehens; *fr*—frontal; *is*—intertemporal-supratemporal; *lc*—lateral commissure; *le*—lateral ethmoid; *lon*—lamina orbitonasalis; *lr*—lateral ridge; *lsc*—lateral semicircular canal; *naf*—nasal fossa; *oa*—occipital arc; *orc*—orbital cartilage; *osc*—superior occipital cartilage; *p*—parietal; *pft*—prefrontal; *pro*—prootic; *psc*—posterior semicircular canal; *psp*—parasphenoid; *pt*—pterotic; *ptr*—posterotransversal ridge; *pts*—pterosphenoid; *rpf*—rostropalatine facet; *sf*—subtemporal fossa; *sn*—nasal septum; *soc*—supraoccipital; *soccr*—supraoccipital crest; *sp*—sphenotic; *spor*—supraorbital ridge; *t*—tectum cranii; *tcom*—trabecula communis; *tfc*—trigeminofacialis chamber; *ts*—tectum synoticum; *v*—vomer.

laginous, and presents, anteroposteriorly, in a dorsal view, a developed ethmoid plate, from which originates, dorsally, the nasal septum which meets the orbitonasal lamina (Figs. 1D, 2C, 3C). The nasal fossa is developed. The vomer begins the ossification process in a membrane, ventrally to the ethmoid plate. The lateral ethmoid appears on the lateral surface of the orbitonasal lamina (Fig. 1D). In the orbital region, dorsomedially, is seen a cartilaginous bar which constitues the tectum cranii, and which

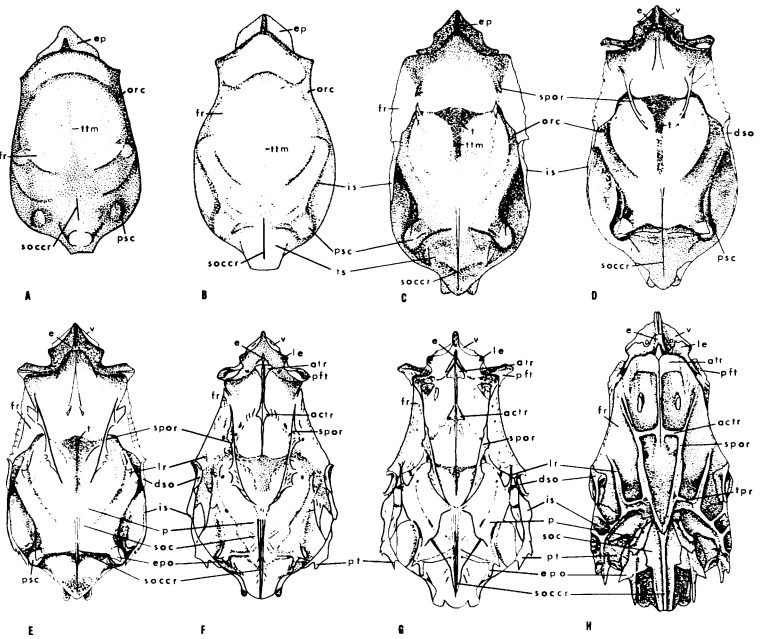

Fig. 2. Dorsal view of larval and juvenile neurocranium of *Micropogonias furnieri*. A) Postflexion larva, 6.8 mm NL; B) postflexion larva, 9.0 mm SL; C) postflexion larva, 13.1 mm SL; D) juvenile, 17.4 mm SL; E) juvenile 23.7 mm SL; F) juvenile, 31.5 mm SL; G) juvenile, 48.3 mm SL; H) adult, 380 mm SL. *actr*—accessory supraorbital ridge; *ttm*—taenia tecti medialis. The other symbols as in Figure 1.

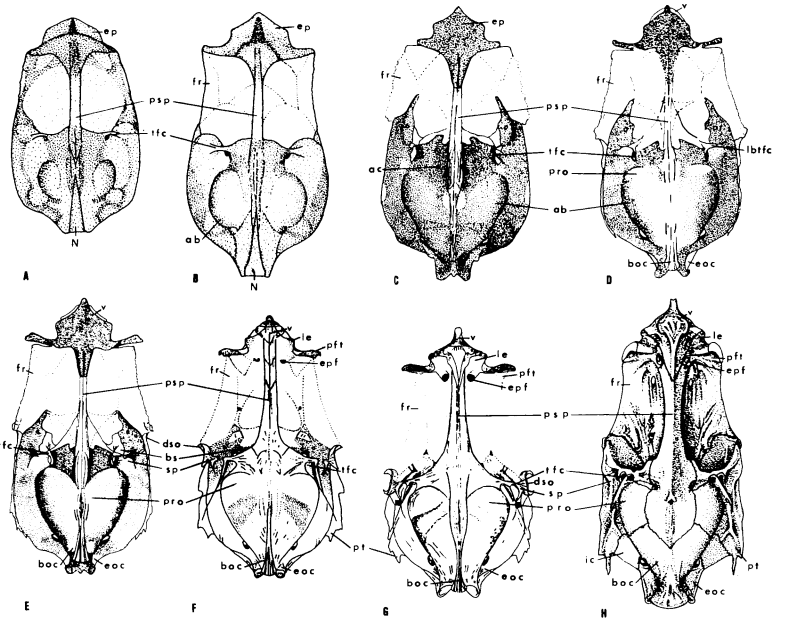

Fig. 3. Ventral view of larval and juvenile neurocranium of *Micropogonias furnieri*. NL and SL as in Figure 2; *ic*—intercalar; *lbtfc*—lateral bridge of trigeminofascialis chamber. The other symbols as in Figures 1 and 2.

takes a posterior direction in the form of a medial bar called taenia tecti medialis. The tectum cranii also proceeds laterally and posteriorly, meeting the otic capsule through the orbital cartilage or taenia marginalis. This is fused to the lateral commissure which forms the outer wall of the trigeminofacialis chamber (Figs. 1D, 2C). Ventrally, two foramina are seen, one for the facial nerve and the other for the palatine branch of the facial nerve. The frontals are present in the form of a transparent bone lamina, covering the taenia tecti medialis, and signs of the supraorbital ridge are observed (Fig. 2C). The other elements are chondrified. The otic region is mostly chondrified, but the supraoccipital area is represented by a transparent bone lamina with a developed supraoccipital crest, covering the tectum synoticum and the taenia tecti medialis (Figs. 1D, 2C). Laterally, the septa for the anterior and lateral semicircular canals are observed. A transparente bony membrane is seen which represents the supratemporal and intertemporal forming a canal which covers the cartilage, the future prootic (Fig. 1D). The future exoccipitals are chondrified and the cartilage proceeds lateroventrally forwards, forming a convex lamella which constitues the auditory bulla (Figs. 1 D, 3C), where the prootic will ossify. In the basicranial region, the basioccipital appears in the form of a chondrified lamella and is excluded from the border of the foramen magnum by the cartilage of the exoccipital. The parasphenoid appears as a mediovental ossified longitudinal bar on the floor of the neurocranium, coming from under the ethmoid plate cartilage and posteriorly interposed between the chondrified laminae of the prootic and basioccipital bone region (Figs. 1D, 3C), forming part of the myodome floor.

15.7 mm SL juvenile.—It presents more bony areas. In the ethmoid region signs of ossification of the anterodorsal portion of the ethmoid bone are seen. In the orbital region, the frontal is more obvious, with a more developed supraorbital ridge, covering the tectum cranii and the taenia tecti medialis, besides the orbital cartilage. In the otic region, the supraoccipital has a longer supraoccipital crest. There are signs that the parietal is becoming ossified. The otic capsule remains chondrified almost throughout. The borders of the supraoccipital and intertemporal are completely ossified. Most of the exoccipital is ossified, enveloping the foramen magnum and defined occipital chondyles. The lateral commissure was replaced by the bony outer wall of the trigeminofacialis chamber, and the anterodorsal portion of the prootic is ossified. In the basicranial region, in a ventral view, the medioventral region of the basioccipital is seen to be ossified, as well as the parasphenoid.

17.4 mm SL juvenile.—The neurocranium presents a larger volume of ossified areas (Figs. 1E, 2D, 3D). In the ethmoid region the vomer is observed to be ossified from its ventral aspect, sutured to the parasphenoid (Fig. 3D). Ossification of the ethmoid in the anterosuperior portion also occurs (Fig. 2D). The other components remain completely chondrified. In the orbital region, the ossified elements are: the frontals with a developed supraorbital ridge (Figs. 1E, 2D) and dermosphenotics present as laminae. In the otic region a small extension of the ossified exoccipital is seen. Little ossification occurs in the region of the intertemporal and supratemporal over lateral semicircular canal (Figs. 1E, 2D). Ossification is seen on the lateral bridge of the trigeminofacialis chamber, formed by the anterior half of the prootic. In the basicranial region the basioccipital presents a small area of ossification, posteriorly (Fig. 3D).

20.3 mm SL juvenile.—Beginning of lateral ridge ossification in the frontal and beginning of sphenotic and pterotic ossification form a lateral carina on the wall of the neurocranium together with the intertemporal and supratemporal. Increased ossification area in the trigeminofacialis chamber involves the prootic, sphenotic and basisphenoid. Remnants of taenia marginalis, taenia tecti medialis and of the post orbital process of the otic capsule are also observed. Most of the otic capsule is chondrified. The medial and lateral extrascapulars are represented by transparent ossified laminae with a central pore. The medial presents projections of the bridge which crosses it in the adult.

23.7 mm SL juvenile.—The ethmoid region presents signs of ossification on the upper external margin of the vomer and inferior one of the lateral ethmoid and in the anterosuperior region of the ethmoid (Figs. 1F, 2E, 3E). In the orbital region the frontals cover the cartilage where the lateral ethmoids will ossify, and also cover remnants of the tectum cranii, of the taenia tecti medialis and of the orbital cartilage. In the frontal the supraorbital ridge is well developed, extending from the ethmoid region until near supraoccipital one. There are signs of the lateral ridge in a lateroposterior position (Figs. 1F, 2E). The basisphenoid presents a larger ossifi-

cation area. In the otic region, the supraoccipital and supraoccipital crest are ossified. The parietals are slightly ossified, but no sutures are observed between them and the supraoccipitals (Fig. 2E). Between the intertemporal and supratemporal a suture zone is observed and they present a longitudinal ridge on the inferior border (Fig. 1F). In ventral view, the otic region pre sents a larger extent of ossification in the exoccipital and prootic (Fig. 3E). Ossification of the sphenotic on the suture line with the prootic is observed, forming the trigeminofacialis chamber. The hyomandibular fossa is still chondrified. The epiotic presents a small bony area (Fig. 2E). In the basicranial region, the basioccipitals present a larger bony area, and no suture zone with the exoccipitals is observed (Fig. 3E). Beneath all these ossified zones can be seen reduced cartilaginous otic capsule.

31.5 mm SL juvenile.—In the ethmoid region, the whole ventral aspect of the vomer is ossified (Figs. 1 G, 2F, 3F). The ethmoid is ossified only in the upper tip, and the rest forms a cartilaginous carina oriented inferiorly until the vomer. The lateral ethmoid shows ossification only in the region of contact with the vomer, and the remainder is cartilage (Fig. 3F). In the orbital region the pterosphenoid is cartilaginous throughout most of its surface, and presents an ossification zone on the border, oriented toward the orbital cavity. The basisphenoid is observed as a small bone lamina (Fig. 1G). In the prefrontal region lateroanterior to the neurocranium cartilage there is an aliform expansion which presents an ossification zone only in the part touching the lateral ethmoid. The frontal presents three obvious ossification zones, one over the orbital region, one in the area of the posterior transversal ridge and the other at the point of the contact with the supraoccipital. Between these zones are observed regions which are quite clear and transparent (Fig. 2F). The supraorbital ridge is well developed. Anterior transversal ridge formation with the growth tips oriented toward each other are observed (Figs. 1G, 2F). The dermosphenotic is present placed over the sphenotic (Figs. 1G, 2F). In the otic region, the sphenotic presents at the external face which is in contact with the prootic forming the ossified hyomandibular fossa, as well as its dorsal region which supports the dermosphenotic (Fig. 1G). The surface which is in contact with the pterosphenoid and frontal is cartilaginous. The pterotic is visible on the laterodorsal border of the neurocranium with the more obvious ossified surface forming an elliptic depression to articulate to the dorsal branch of the hyomandibular. A line of contact with the intercalar (opisthotic) and, dorsally, with a bone border represented by the intertemporal and supratemporal, dorsolaterally at the suture with the epiotic, is cartilaginous. The prootic presents partial ossification: the lateroanterior half which envelops and constitutes the trigeminofacialis chamber is ossified and the lateroposterior, convex half, which constitues most of the auditory bulla, is cartilaginous (Fig. 3F). The epiotic, located at the posteromedial angle of the otic capsule, presents a central ossification zone. The subtemporal fossa region which borders on the pterotic and, posteriorly, on the exoccipital is cartilaginous. The intercalar is represented by a long ossified lamina whose borders are cartilaginous (Figs. 1G, 2F). The exoccipital is one of the elements of the otic capsule which is mostly ossified, and in the suture between the symmetrics over the foramen magnum, a cartilaginous region is observed. The supraoccipital presents a strongly ossified mediodorsal region and supraoccipital crest. The parietal is represented by a very small, slightly ossified plaque, in which the most obvious ossification zone is a sign of its crest (Figs. 1G, 2F). The borders are not defined.

35.2 mm SL juvenile.—The advanced ossification is observed as compared to the 31.5 mm juvenile, with few areas of cartilage, limited to the ethmoid, orbital and otic regions. In the ethmoid region the vomer presents a cartilaginous anterior carina; the ethmoid is cartilaginous only at the borders of contact with the vomer and lateral ethmoids. The lateral ethmoid presents a large cartilaginous area, which continues along the rostropalatine and ethmopalatine facets. The nasals are bony laminae. In the orbital region, the pterosphenoid is ossified over most of its surface, with cartilaginous contact borders to the sphenotic, prootic and frontal. The basisphenoid has a short narrow bony tip in the direction of the parasphenoid. The prefrontal presents a central ossification zone which extends to the lateral border. The frontal is ossified almost throughout, with transparent zones where the points of ossification meet over the orbital region. The lateral ridge is developed with the growth extremities close to each other. There are signs of anterior transversal and accessory supraorbital ridges. The dermosphenotic presents a slightly ossified lamina, with signs of bridge formation through two ossification tips, oriented toward each other. The otic region presents only a few cartilaginous zones, limited to the sphenotic, prootic

and parietal. In the sphenotic, the borders of contact with the pterosphenoid, prootic and frontal are condrified. The lateroposterior half of the prootic is chondrified up to the basioccipital border. The cartilaginous area is reduced in the epiotic subtemporal fossa. In the parietal the borders of contact with the supraoccipital and frontal are not visible.

48.3 mm SL juvenile.—The neurocranium presents good ossification, continues to assume additional adult characteristics, with a reduction of the cartilage areas in the ethmoid, orbital and otic regions (Figs. 1H, 2G, 3G). The ridges are incomplete in the frontal, parietal, dermosphenotic, intertemporal and supratemporal bones. In the ethmoid region, the rostropalatine and ethmopalatine facets of the lateral ethmoid are still cartilaginous, as is the anterior of the vomer (Figs. 1H, 3G). In the orbital region, the basisphenoid is ossified, forming the myodome roof. The lateral aliform expansion and facet supporting the lacrimal are both cartilaginous in the prefrontal. The frontal is completely ossified, as are the supraorbital and lateral ridges. The transversal anterior and accessory supraorbital ridges are forming (Figs. 1H, 2G). There are no signs of the posterior transversal and accessory posterior transversal ridges. The otic region presents small areas of cartilage limited to the prootic and sphenotic (Fig. 3G).

380 mm SL adult.—The neurocranium is completly ossified. In the ethmoid region stands out a strong anterior prominence of the bony keel vomer, of the rostropalatine facet and, ventrally, of the ethmopalatine facet (Figs. 1I, 2H). There is also a strong anterosuperior prominence of the ethmoid. In the orbital region, the transversal anterior ridge, accessory supraorbital ridge, the posterior transversal and acessory posterior transversal ridges of the frontal are already developed (Fig. 2H). The dermosphenotic ridge is completely ossified. There is a bony interorbital septum well developed. In the otic region the sphenotic and prootic are completely ossified (Fig. 1I). This forms the convex prominent auditory bulla that contains the otolith, the anterior semicircular channel and the trigeminofacialis chamber. This is formed by bony bridges that delimitate foramina in the anterolateral prootic wall, at the limit with the sphenotic. The intertemporal-supratemporal forms laterally a large channel of the lateral line and anteriorly it fuses with the sphenotic. Posteriorly it sutures to the pterotic. This suture can be seen as a very fine line (Figs. 1I, 2H). The supraoccipital ridge is long, high and distributed medially over all the supraoccipital. The epiotic located at the posteromedial angle of the otic capsule, covers the posterior vertical semicircular channel. Posteriorly, it bifurcates in a medial and a lateral branch, the medial branch being very long, projecting backwards in the posterior contour of the neurocranium (Fig. 2H). In the basicranial region, the parasphenoid presents a prominent longitudinal ventral keel. This ventral keel is only slightly visible at the 48.3 mm SL specimens. The basioccipital constitutes the posterior ventral floor of the neurocranium, separeted of the edge of the foramen magnum by the exoccipital and forms one of the three occipital condyles (Figs. 1I, 3H).

Discussion

According to Mook (1977), the ossification sequence of the skull is probably a conservative process among fishes, and Weisel (1967) states that regions in which ossification initially occurs are those sudjected to high stress, such as mandibular bones, responsible for feeding and the branchial bones, which provide support and protection for respiratory organs.

After observing and comparing a series of 60 specimens of *Micropogonias furnieri* during the different stages of development (Fig. 4), we can confirm that the bones which ossify first in the neurocranium are those which are placed in the stress areas, such as the parasphenoid, one of the first bones to form, since it constitutes the anterior floor of the neurocranium; the frontals which close the neurocranium dorsally, protecting the brain and supporting the lateral line of the anterior dorsal half of the cranium; the supraoccipitals and exoccipitals, which establish the articulation, through the occipital condyles, with the first vertebra.

In the ehtmoid and orbital regions it can be seen that until about 23 mm SL it is not possible to distinguish the prefrontal from the lateral ethmoid, which appears as a single cartilaginous structure which ossifies lately. However since about 31 mm SL there is a limit between both the bones through the ethmopalatine facet, located at the lateral ethmoid, which has more bony surface, while the prefrontal region shows a large cartilaginous area. Only at 48.3 mm SL the frontal presents ossifying zones and only in the adults these bones are perfectly visible. Nevertheless it is not possible to distinguish the border lines

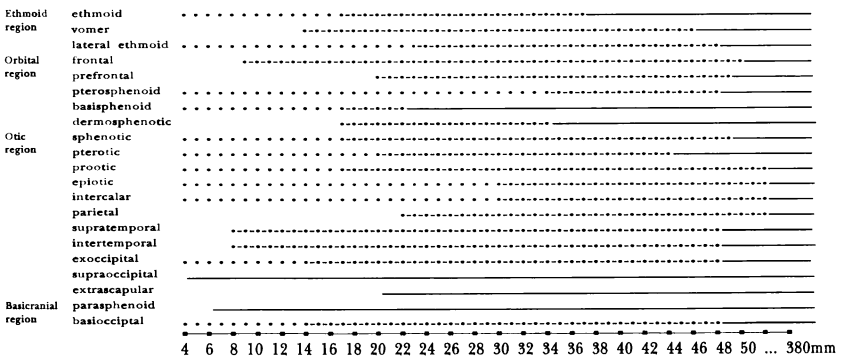

Fig. 4. Development sequence of head skeleton of *Micropogonias furnieri* larvae and juveniles. Dotted line, cartilaginous state. Dotted line and solid line, partially ossified state (from first signs to 99% ossified). Solid line, ossified state.

between them, corroborating the opinion of the Patterson (1977) who says "there is no evidence of a dermal prefrontal in any teleost either as an independent bone or as a component of the lateral ethmoid, while the endoskeletal lateral ethmoid appears to be a primitive actinopterygian feature" (Figs. 1, 2).

In the orbital and otic regions it is seen that the dermosphenotic ossifies very early and leans on a cartilaginous base that will be replaced by the sphenotic, which ossifies later, at 35.2 mm SL. In this stage there is a fusion, between both these bones. The endochondral pterotic and the intertemporal-supratemporal (dermopterotic) end up fusioning as a result of the approximation of the ossifying centers (Patterson, 1977). During the ontogeny of *Micropogonias furnieri*, it is observed that the intertemporal supratemporal shows a large ossified area at 20.3 mm SL, while the pterotic maintains a large cartilaginous area and only at 48.3 mm SL occurs the complete ossification of these bones. In the adult the intertemporal-supratemporal is a single bone that forms the laterodorsal edge of the neurocranium and the laterodorsal canal for the lateral line (Figs. 1I, 2H).

The endochondral supraoccipital appears as a small ossified area at 23.7 mm SL and completes ossification at 48.3 mm SL, covering, at the adult, the neurocranium dorsoposterior third portion, limited anteriorly by the frontal, anterolaterally by the parietal, posteroventrally by the exoccipital and posterolaterally by the epiotic. The supraoccipital ridge, according to Patterson (1977), is an external growth membrane bone of the endochondral bone, that becomes visible as a short posterior bony lamina. At 13.1 mm SL, it is a bony ridge that grows progressively until the point that, in the adult, it extends dorsomedially over all the supraoccipital (Figs. 1D, 2C).

The parietal covers the dorsum of the neurocranium in a parasagittal axis and is ossified at 48.3 mm SL, though the ridge and the sutures with the frontal, pterotic and epiotic are not visible. In the adult it is a plane bone with a well developed bridge crossing it over anteroposteriorly and parasagittaly (Fig. 2G). The prootic and sphenotic ossification take place lately, because at 48.3 mm SL it is observed that a large transversal cartilaginous area at the prootic and its borderline with the sphenotic is not well defined. However, the hyomandibular fossa that reasults from the articulation between these bones and is of great importance in the suspension of the maxillomandibular apparatus, is already defined. The trigeminofacialis chamber has not got completely ossified bridges, as in the adult (Figs. 1H, 1I, 3G, 3H).

Acknowledgments

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Micropogonias furnieri（スズキ目：ニベ科）の神経頭蓋の発達

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Micropogonias furnieri（スズキ目，ニベ科）の神経頭蓋の骨格形成について，軟骨の硬骨化を中心に記載した．前屈曲期仔魚-稚魚（3.8–48.3 mm）と成魚（380 mm）を透明化・染色して観察した．3.8–4.2 mm の前屈曲期仔魚では，神経頭蓋は完全に軟骨性であった．5.8–7.8 mm の屈曲期仔魚では，額骨と上後頭骨は透明な薄板であったが，篩骨と耳殻部は軟骨性であった．約 8.0–14.0 mm の後屈曲期仔魚では，多数の化骨域が観察された．すなわち，額骨の眼上隆起，上後頭骨とその隆起部，ろ頂骨，副蝶形骨，外後頭骨の一部，三叉・顔面室の壁面，などである．約 14.0–48.3 mm SL の稚魚では，主要な化骨域は篩骨，眼窩部，耳殻部で，特に骨の化骨が顕著である．鋤骨と前額骨の化骨は弱い．額骨は部分的に化骨するが，隆起部分は不完全か，未化骨である．ろ頂骨，後頭骨と上後骨隆起は，速やかに化骨する．耳殻部の化骨は比較的遅く，48.3 mm でも軟骨部が多い．副蝶形骨と基底後頭骨は，14.0 mm から化骨部が大きくなる．380 mm の成魚では，全域が完全に化骨する．なお，上側頭骨と翼耳骨の縫合部は，識別できない．これらの構造は，発生過程の極く初期に融合する．