

# Characters of the Lateral-Line System and Their Use in Taxonomy of *Paralichthys*, *Hippoglossina* and *Lioglossina* (Paralichthyidae, Pleuronectiformes)<sup>1</sup>

E. P. Voronina<sup>a</sup> and J. M. Díaz de Astarloa<sup>b</sup>

<sup>a</sup>Zoological Institute, Russian Academy of Sciences, Universitetskaya emb. 1, St. Petersburg, Russia

<sup>b</sup>Instituto de Investigaciones Marinas y Costeras-CONICET-IDRC, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

e-mail: epvoronina@mail.ru

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**Abstract**—A morphological study of eight species of *Paralichthys*, two species of *Hippoglossina*, and *Lioglossina tetrophthalma*, has revealed head lateral-line canal topography differences of taxonomic value. In species of *Paralichthys*, segment of the supraorbital canal in nasale of the blind side is connected with other canals and canaliculi are ramified, whereas in species of *Hippoglossina* this segment is not connected and canaliculi are not ramified. These different character states corroborate the generic distinction between *Paralichthys* and *Hippoglossina*. The connection of the supraorbital canal in nasale of the blind side with other canals and ramified canaliculi found in *L. tetrophthalma* and *P. oblongus* are against regarding them as *Hippoglossina* species. It appears necessary to restore the monotypic genus *Lioglossina* and to place *P. oblongus* in the genus *Paralichthys* until new morphological or molecular data are obtained. *Paralichthys* species vary in the degree of ramification of canaliculi, presence or absence of infraorbital canal segment in the lacrimale of the ocular side and posterior line of CST. Differences in lateral-line canal topography of *H. macrops* and *H. bollmani* were not found.

**Keywords:** morphology, taxonomy, lateral-line canals of the head, *Paralichthys*, *Hippoglossina*, *Lioglossina*

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Close related genera *Paralichthys* Girard, 1858 and *Hippoglossina* Steindachner, 1876 include 21–22 and 6–7 species respectively. Many of them are of great commercial value and a number of studies on their biology have been published (Norman, 1934; Ginsburg, 1952; Díaz de Astarloa and Munroe, 1998, Díaz de Astarloa, 2005). Taxonomy of the family Paralichthyidae and these genera in particular, however, has been poorly studied. Diagnosis of many species is hampered by their great similarity and ambiguous original descriptions, their placement in particular genera being weakly substantiated. As an example, cycloid scales on both sides of the body and uniform fine teeth were pointed out as diagnostic characters for *Lioglossina* based only on the description of *L. tetrophthalma* (Gilbert, 1890). It has been shown later that these and few other characters (size of eyes, dorsal fin position, development of “accessory branch of the lateral-line”, interorbital distance) are insufficient for corroborating the validity of *Lioglossina* (Ginsburg, 1952). Further consideration of this genus as a synonym of *Hippoglossina* has been accepted in the literature (Hensley, 1995; Eschmeyer, 2010).

There are difficulties in establishing the taxonomic status of *P. oblongus* (Ginsburg, 1952). In contemporary literature this species is regarded as *H. oblonga* (Evseenko, 2000; Munroe, 2006) and *P. oblongus* as well (Nelson et al., 2004).

It is noteworthy that molecular investigations have been performed for a few number of paralichthyid species. Therefore, obtaining new morphological data is undoubtedly important for the taxonomy understanding of this group.

Some characters of the lateral-line system (ramification of canaliculi, the presence or absence of the infraorbital canal of the ocular side and trunk canal) have been used in pleuronectiform taxonomy (Norman, 1934; Hensley and Ahlstrom, 1984). A wider comparison of lateral-line canals of the head in different pleuronectiform taxa has shown the informative value of this system characters (Voronina, 2009). The presence of lateral-line canal segments in the skull bones has been noted in osteological studies of paralichthyids, among those, species of the genus *Paralichthys* (Amaoka, 1969; Díaz de Astarloa, 2005). However, the lateral-line system has not been considered in detail so far. The aim of the present study is to examine the topography of the lateral-line canals of the head in

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species of the genera *Paralichthys*, *Hippoglossina* and *Lioglossina* in order to use them as taxonomic and diagnostic tools.

## MATERIAL AND METHODS

Lateral-line canals of the head have been studied in two species of *Hippoglossina*, one species of *Lioglossina* and eight species of *Paralichthys*:

*Hippoglossina bollmani*: four specimens, SL 100–172 mm USNM no. 41147 (paralectotype), 7°56'N, 79°41'30"W; ZMMGU no. 13543, northern coast of Peru; MNHN 2002/0082, 2°10'S, 79°55'W; *H. macrops*: 14 specimens SL 85–205 mm, ZIN no. 46679–ZIN no. 46685, 52181, 41°–45°S, 74°–75°W;

*Lioglossina tetraphthalma*: two specimens SL 240 n 260 mm, ZMMGU no. 13478, 3°35'S, 80°47'W; *Paralichthys californicus*: two specimens SL 120 h 127 mm, ZIN no. 8100, coast of California, off San Diego;

*P. dentatus*: two specimens SL 260 and 245 mm, ZIN no. 23696, Southern Atlantic, Chesapeake Bay; *P. isosceles*: five specimens SL 125–275 mm, ZIN no. 54422, Northern Patagonia near Valdes Peninsula; ZIN no. 54423, 42°03'S, 60°48'W; *P. oblongus*: six specimens SL 220–370 mm, ZIN no. 23700, Cape May; ZIN no. 48269, 40°28'N, 67°20'W; *P. olivaceus*: three specimens SL 105–295 mm, ZIN no. 21723, Japan, Hondo; ZIN no. 23820, Yellow Sea, Qingdao, Shandong Province; 45205, Yellow Sea Qingdao; *P. orbignyianus*: one specimen SL 170 mm, ZIN no. 54424, off Mar del Plata; *P. patagonicus*: three specimens SL 65–100 mm, ZIN no. 54425, off Mar del Plata.

Methods and terminology accepted in the study of lateral-line canals of different teleost taxa including Pleuronectiformes (Makushok, 1961; Neyelov, 1979; Webb, 1989; Mandritsa, 2001; Voronina, 2009) have been used. Numbers of infraorbitalia and extrascapularia have been defined in the studied specimens. Description of canal containing bones has been made on cleared and alizarin stained specimens of *Paralichthys olivaceus* (ZIN 45205 SL 295 mm).

## RESULTS AND DISCUSSION

The main topography of lateral-line canals of the head in the species studied largely agreed to that described earlier in representatives of the suborder Pleuronectoidei (Traquiar, 1865; Cole and Johnstone, 1902; Voronina, 2009). There are four canals (Fig. 1): symmetrical temporal (*CT*) and preopercular-man-

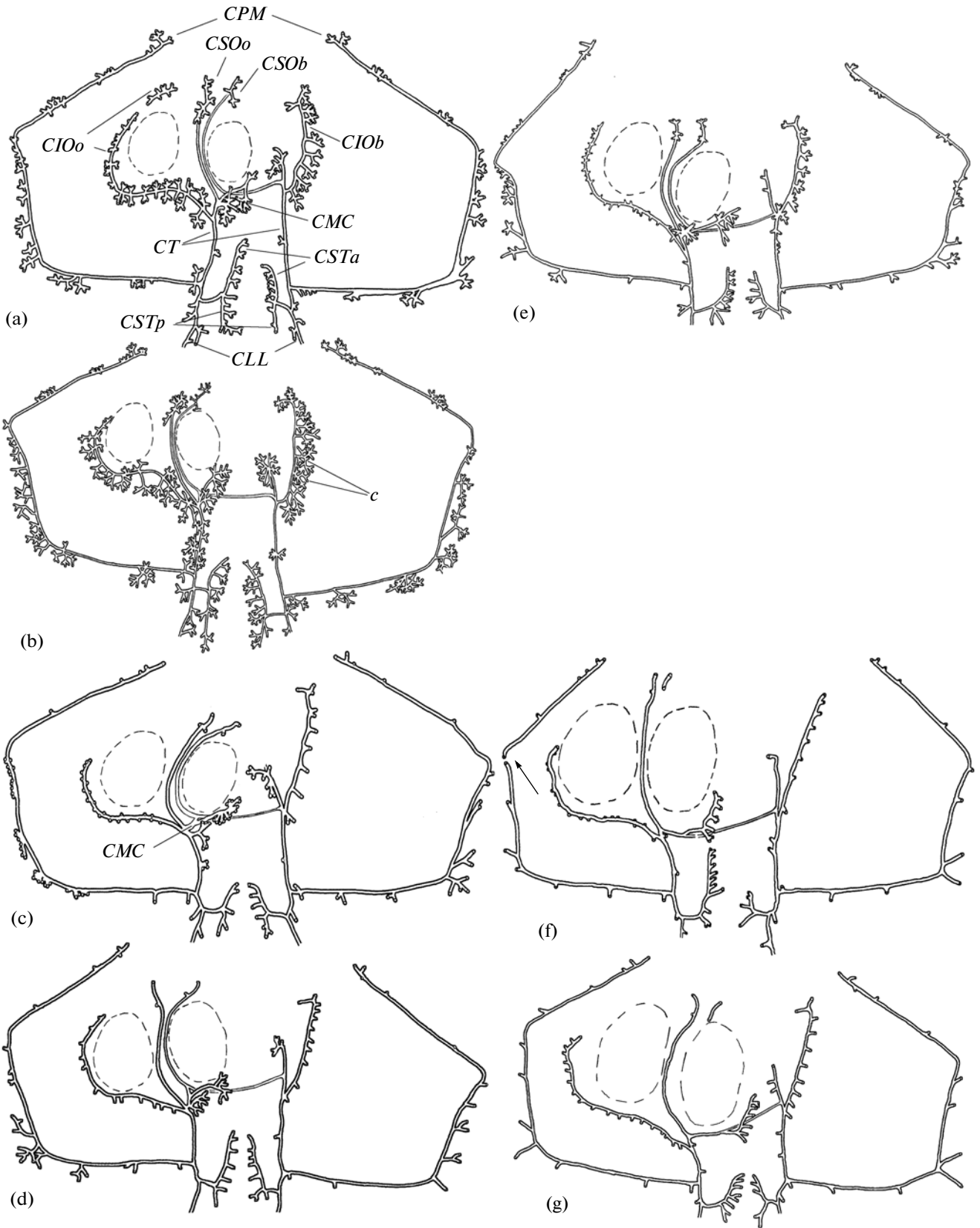
dibular (*CPM*), asymmetrical supraorbital (*CSO*) and suborbital canals (*CIO*); coronal commissure (*CMC*); interrupted supratemporal commissure, transformed into a symmetrical supratemporal canal *CST*. The position of canals in the skull bones of *P. olivaceus* (Fig. 2) corresponds to previous osteological description of this species (Amaoka, 1969) and *P. patagonicus*, *P. orbignyianus* and *P. isosceles* as well (Díaz de Astarloa, 2005).

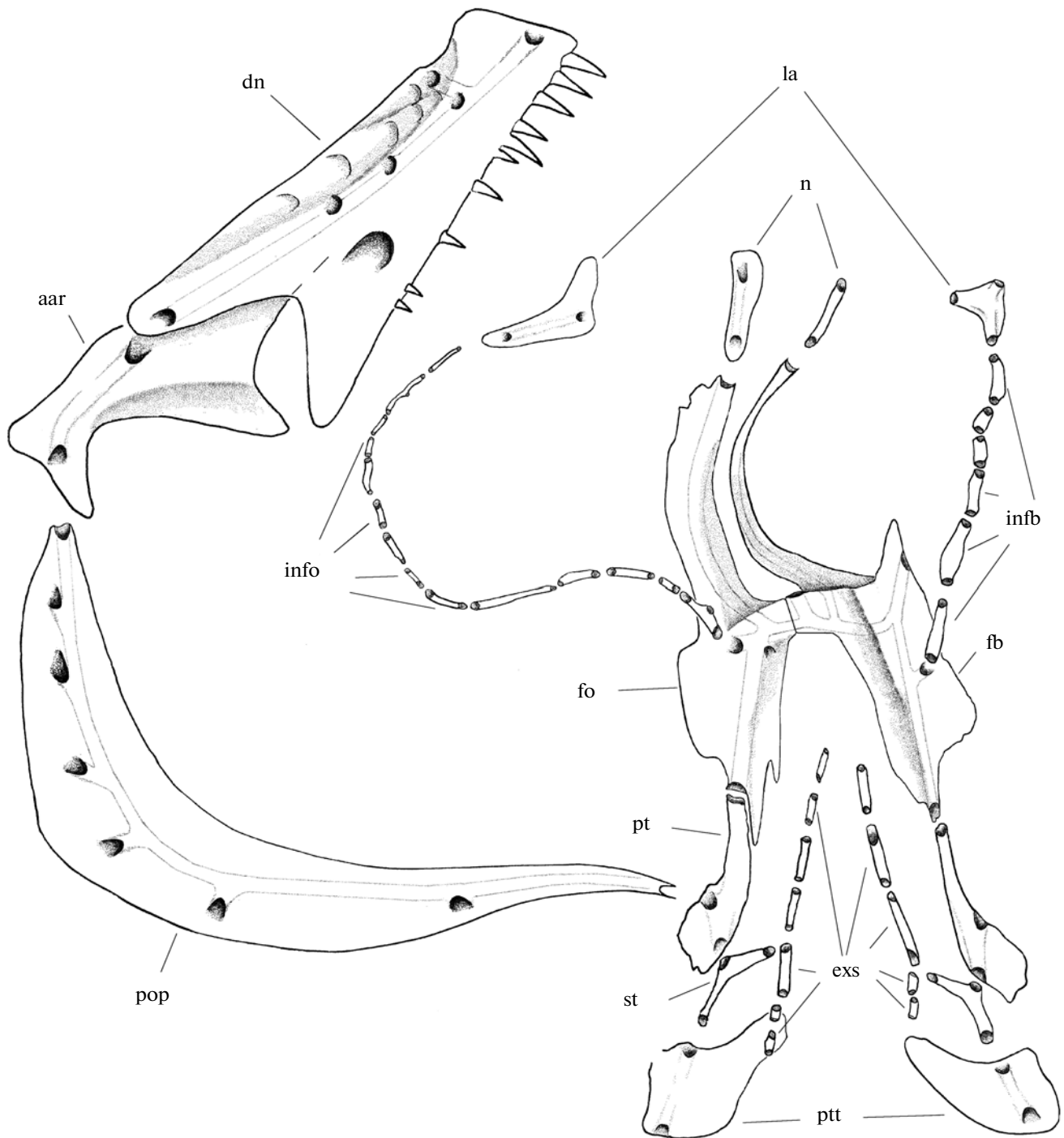
Ramification of the canaliculi varies in studied species (Fig. 3). This character has not been considered in the literature earlier, although a series of pores of *CPM* has been noted in *P. patagonicus*, *P. orbignyianus* and *P. isosceles* (Díaz de Astarloa, 2005). According to our data, canaliculi are ramified in all species of *Paralichthys* and in *L. tetraphthalma*; they are ramified least of all in *P. oblongus* and *P. isosceles*. In *H. macrops* and *H. bollmani* canaliculi are not ramified, excluding the canaliculus of *CMC* and few canaliculi in *CST*.

*CSO* of the ocular side passes through nasale with 2 fontanelles and frontale with 5 fontanelles, connecting there with *CT*, *CMC* and *CIO* (Fig. 2). In the nasal region the canal opens by two primary and numerous secondary pores in species of *Paralichthys* and in *L. tetraphthalma* and only by 2 primary pores in *H. macrops* and *H. bollmani*. *CSO* of the blind side in *Paralichthys* species and *L. tetraphthalma* passes through nasale and frontale, connecting with other canals. In *H. macrops* and *H. bollmani* a segment of *CSO* in nasale of the blind side opens by two pores and is not connected with other canals, interorbital part of *CSO* is absent.

*CIO* of the ocular side passes through 13–18 infraorbitalia and opens by 13–20 primary pores. *CIO* of the blind side passes through lacrimale and 5–6 infraorbitalia and opens by 8–10 primary pores. This is consistent with the reference to *CIO* of the ocular side in *Paralichthys* and *Hippoglossina* (Hensley and Ahlstrom, 1984), 5–7 infraorbitalia of the blind side in *P. olivaceus* (Amaoka, 1969) and 12–18 infraorbitalia of the ocular side and 4–6 infraorbitalia of the blind side in *P. patagonicus*, *P. orbignyianus* and *P. isosceles* (Díaz de Astarloa, 2005). According to our data, *P. dentatus*, *P. olivaceus*, *P. orbignyianus*, and *P. californicus* have segment *CIO* in lacrimale of the ocular side not connected with the rest part of this canal. In *P. patagonicus* such segment is present in 1 specimen, whereas it is absent in 2 other specimens. Segment *CIO* in lacrimale of the ocular side is absent in the studied specimens of *P. isosceles*, *P. oblongus*, *L. tetraphthalma*, *H. macrops* and *H. bollmani*. Presence of

**Fig. 1.** Lateral-line canals of the head in *Paralichthys* and *Hippoglossina* species: (a) *Paralichthys olivaceus*; (b) *P. orbignyianus*; (c) *P. oblongus*; (d) *P. isosceles*; (e) *Lioglossina tetraphthalma*; (f) *Hippoglossina macrops*; (g) *H. bollmani*. *CIOb*—infraorbital canal of the blind side; *CIOo*—infraorbital canal of the ocular side; *CMC*—coronal commissure; *CPM*—preoperculo-mandibular canal; *CSOb*—supraorbital canal of the blind side; *CSOo*—supraorbital canal of the ocular side; *CSTa*—anterior branch of supratemporal canal; *CSTp*—posterior branch of supratemporal canal; *CT*—temporal canal; *CLL*—trunk canal; c—canaliculi. (→)—break in *CPM*.





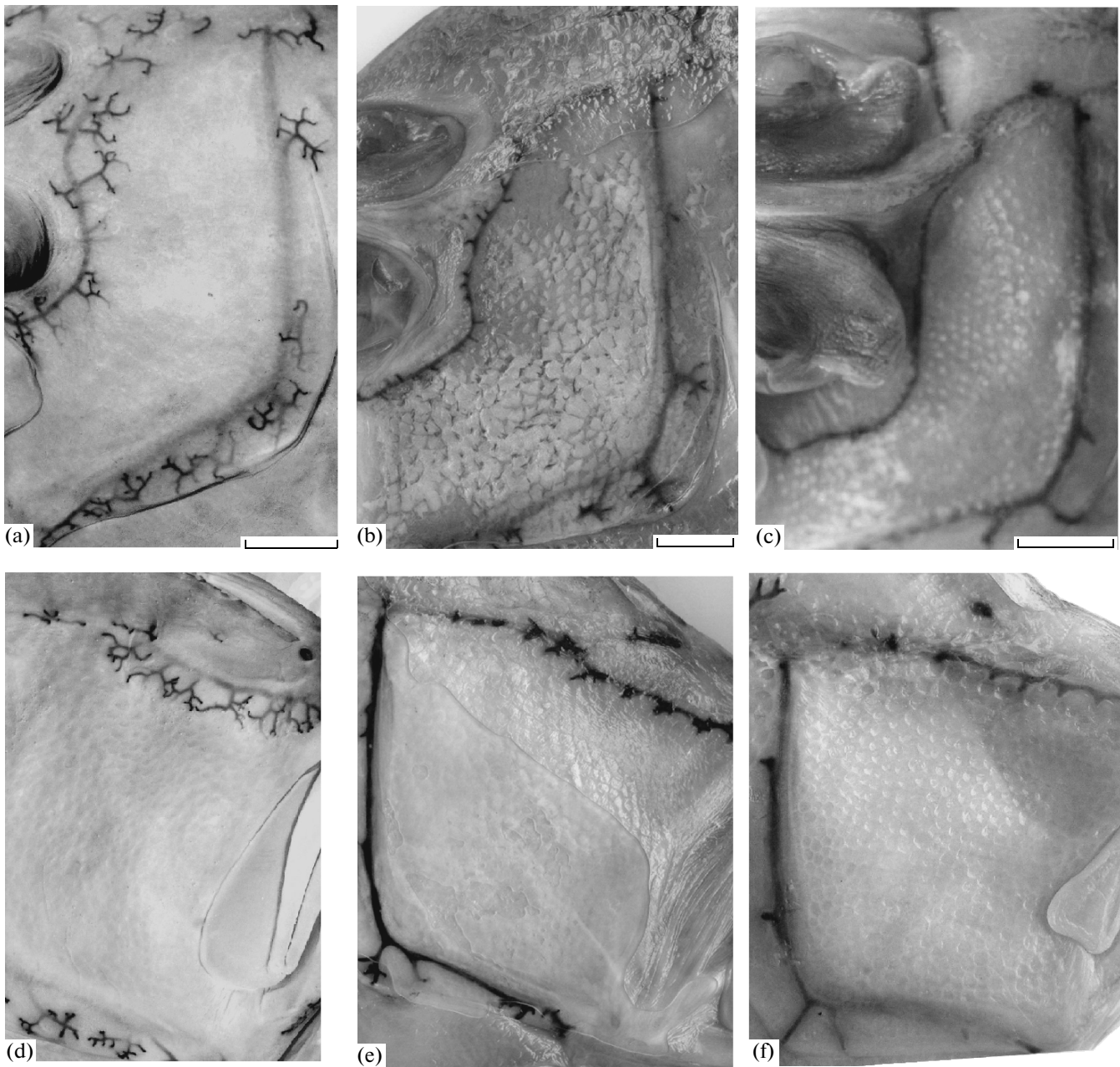
**Fig. 2.** Skull bones of *Paralichthys olivaceus* (SL 295 mm), containing lateral-line canals: aar—angulo-articulare, exs—extrascapulare, dn—dentale, fb—frontale the blind side, fo—frontale of the ocular side, infb—infraorbitale, info—infraorbitale of the ocular side, la—lacrimale, nb—nasale of the blind side, no—nasale of the ocular side, pop—preoperculum, ptt—posttemporale, st—supratemporale, pt—pteropticum. Preoperculo-mandibular canal of blind side is not shown.

infraorbital canal in lacrimale has been earlier noted in *P. isosceles*, *P. orbignyanus* and *P. californicus* (Díaz de Astarloa, 2005).

*CMC* passes through frontalia and connects canals of both sides of the head in all studied species. Long canalculus of the unpaired pore *CMC* passes through

frontale of the blind side. Its free part, located in the skin near the posterior edge of the upper eye, is ramified and opens by 4–15 pores.

*CT* passes through frontale, pteroticum with 3 fontanelles and posttemporale with 2 fontanelles.



**Fig. 3.** Lateral-line canals and canaliculi stained with methylene blue: (a), (d) *Paralichthys orbignyanus* SL 170 mm; (b), (e) *Lioglossina tetrophthalma* SL 260 mm; (c), (f) *Hippoglossina bollmani* SL 172 mm. (a), (b), (c) ocular side, (d), (e), (f) blind side. Scale bar 1 mm.

*CPM* pass through dentale with 6, angulo-articulare with 2 and praeoperculum with 8 fontanelles. In *Paralichthys* species and *L. tetrophthalma* the canal is continuous on both sides of head. In 15 specimens of *H. macrops* a break between the praeopercular and mandibular parts of the ocular side has been found, in two specimens the break is not complete. In paralectotype of *H. bollmani* this break is present on both sides of head, in three other studied specimens no break in *CPM* has been found.

*CST* is developed on both sides of the head in all species examined and passes through supratemporale with 3 fontanelles and through 2–7 small extrascapularia. In *Paralichthys* species and *L. tetrophthalma* the canal opens by 5–9 primary and numerous secondary pores, in *H. macrops* 3–10 pores occurred on the ocular side and 2–4 pores on the blind side. This amends the currently held opinion that notable *CST* is absent in *Paralichthys* (Norman, 1934; Amaoka, 1969) and is consistent with description of *CST* not reaching base

of rays of dorsal fin in *P. orbignyana* (Díaz de Astarloa et al., 2006). There are anterior and posterior branches *CST* with 2–6 and 2–4 small extrascapularia respectively in majority of *Paralichthys* species. The posterior branch of *CST* with extrascapularia is absent in *P. isosceles*, *P. oblongus*, *H. macrops* and *L. tetrophthalma*.

The trunk canal on both sides of the body with an arch above the pectoral fin has been described before (Norman, 1934). No additional canals on the caudal fin have been found in the species studied.

Comparing data obtained in previous studies of pleuronectiform lateral-line system (Voronina, 2009) allows assessing the value of the revealed differences and making a number of taxonomic conclusions.

Connection of *CSO* segment in nasale of the blind side with other canals is most important, since it is related to bone (interorbital process of frontale) structure but not only to the reduction of the connective tissue part of the canal. This character is constant for species of one genus as it has been shown in five Pleuronectiform families. The different states of this character have been noted for other families representatives—continuous *CSO* of the blind side in *Pseudorhombus pentophthalmus* (Paralichthyidae) and absence of connection of *CSO* segment in nasale with other canals in *Engyprosonon grandisquama* (Bothidae) (Sasaki et al., 2007). Another character—the ramification of canaliculi, is also constant in congeners, although its slight individual and interspecific variability takes place. In species of *Paralichthys* segment of the supraorbital canal in nasale of the blind side is connected with other canals and canaliculi are ramified, whereas in species of *Hippoglossina* this segment is not connected and canaliculi are not ramified. The different states of these main characters corroborate distinct genera *Paralichthys* and *Hippoglossina*. The presence of such connection and ramified canaliculi in *L. tetrophthalma* and *P. oblongus* does not confirm the placement of these species in *Hippoglossina*. On the other hand, the similarity of their lateral-line system topography with that of *Paralichthys* species does not prove their position in this genus. It appears necessary to restore the monotype genus *Lioglossina* with species *L. tetrophthalma*, and to consider *P. oblongus* as belonging to the genus *Paralichthys* until further morphological or molecular data are obtained.

Presence or absence of *CIO* segment in lacrimale of the ocular side, of the break in *CPM* of the ocular side and posterior branch of *CST* are species specific characters. However, their individual variability requires further statistic analysis. As an example, the individual variation apparently accounts for lamella-like (i.e. not containing canal) lacrimale of the ocular side in *P. pentophthalmus* (Sasaki et al., 2007), whereas the presence of canal in this bone has been demonstrated for this and some other *Pseudorhombus* species (Amaoka, 1969).

In the genus *Paralichthys* two species, *P. oblongus* and *P. isosceles*, are distinguished by the least ramifica-

tion of canaliculi, absence of segment *CIO* in lacrimale and of the posterior branch of *CST* with extrascapularia.

Sympatric *H. macrops* and *H. bollmani* differ by the presence of ctenoid scales on the blind side—in the last third of the body in the former species and reaching gill opening or at least the middle of the trunk canal arch in the latter. Specimens studied in the present paper were identified accordingly to this character. The similarity of lateral-line canal topography implies their close relationship or conspecificity.

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