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RESEARCH NOTE

Gross morphology of the cephalic sensory canals of *Strangomera bentincki* (Norman, 1936) (Teleostei: Clupeidae)

Morfología macroscópica de los canales cefálicos sensoriales en *Strangomera bentincki* (Norman, 1936) (Teleostei: Clupeidae)

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Abstract.- The anatomy, disposition and extension of the main cephalic sensory canals and associated structures in a clupeiform from Chile, *S. bentincki*, are provided for first time. Ten cephalic canals were identified: supraorbital, infraorbital, anterorbital, postorbital, preopercular, mandibular, ethmoidal, temporal, postemporal and extrascapular. Due to the scarce literature in sensory structures regarding Chilean Clupeiformes, it is necessary more studies about those features for the respective comparisons to obtain a better understanding of the systematic and comparative ethology of the sardines and to have an integral view of the cephalic sensory system of canals in this order.

Key words: Lateral line, Physostomous, sardines, Chile

INTRODUCTION

Anatomy of cephalic sensory canals are relevant to systematic studies of fishes of the order Clupeiformes (*e.g.*, Grande 1985, Ohshimo 1999, Di Dario 2004, Di Dario & de Pinna 2006). Number and disposition of cephalic canals are somewhat conservative among teleosts, however, variations in the extension and connections between different branches of the system have been identified (Tracy 1920, Greenwood 1968, Nelson 1972, Webb 1989, Kasumyan 2003, Di Dario 2004, Di Dario & de Pinna 2006, Stephens 2010).

Strangomera bentincki (Norman, 1936) is endemic to the Chilean coast. The species was included in different taxonomic studies (de Buen 1958, Aranis *et al*. 2007, Silva & Pequeño 2007), and is frequently captured by the fishing float (Coquimbo, Valparaiso and of the south to Talcahuano, Isla Mocha), together with other species of the Clupeiformes. In spite of those studies, knowledge on the sensory system of clupeomorphs of the region is still scarce.

This species has a complex system of cephalic sensory canals, which is part of the acoustic lateral system. This sensory system together with other structures (*i.e.*, *recessus lateralis*, otic bullae, supratemporal system) are involved in the schooling formation, detection of water vibrations and detection of predators, helping also for the position of the school fish and the detection of pressure during the vertical migration (Whitehead 1985, Di Dario 2004, Di Dario & De Pinna 2006).

The main ramifications of the supraorbital, infraorbital, preopercular and pterotic canals converge on an intracranial space of the otic region, the *recessus lateralis* (Grande 1985, Whitehead 1985, Di Dario 2004). This structure is a special chamber, typical of the Clupeiformes, located in the interior of the skull and has three main openings (anterior, medial and posterior) and their internal wall have a membrane that separates a gas-filled chamber (from the swimbladder) from perilymphatic liquid (surrounding the inner ear) (Tracy 1920, Whitehead 1985, Di Dario 2004, Di Dario & De Pinna 2006).

The function of this structure is not accurately known, but it is probably related to the detection and analysis of small vibrational pressures of water and displacement of fish (Tracy 1920, Grande 1985, Whitehead 1985, Webb 2013). Moreover, the otic region hosts another important structure, the otic bullae, that is closely associated with the *recessus lateralis*, which is also connected to the swimbladder, where thin tubes enter to the skull up to the otic bullae, surrounds it in capsules prootic and pterotic bones (Whitehead 1985, Whitehead & Blaxter 1989, Ganias *et al*. 2015).

Herein, the anatomy, disposition and extension of the main cephalic canals and associated sensory structures of *Strangomera bentincki* are described for first time. It is hoped that an increase in the knowledge of that system will led to improvements in the taxonomy and systematics of the Clupeiformes, in addition to behavioral and ecological studies of this species.

Materials and methods

Material examined

Fifteen specimens of *Strangomera bentincki* were examined, all captured in Niebla, Valdivia (XIV Region) of Chile. Total length varied between 84.6 and 103 mm, and cephalic length varied between 16.6 and 26 mm. The cephalic sensory canals were examined by clearing and staining techniques, following Taylor (1967). Specimens were photographed to register the cephalic canals. The diaphanized specimens were deposited in the fish collection of the Universidad de Concepcion Chile, with the number: MZUC - UCCC 45082 and 45083.

To observe the swimbladder and its connection with the otic region, which are structures associated with the acoustic lateral system, one specimen (LT= 100 mm) was dissected (Fig. 2).

Cephalic canals and associated bones abbreviation are: AOC antorbital canal, SOC supraorbital canal, POC postorbital canal, IOC infraorbital canal, MC mandibular canal, PPC preopercular canal, PTC postemporal canal, ESC extrascapular canal, EC ethmoidal canal, TC pterotic canal, fr frontal bone, pa parietal bone, tem temporal bone.

Results and discussion

Morphologic study

In the specimens studied, 10 narrowed and branched cephalic canals were observed (Figs. 1a and b):

Supraorbital canal (SOC): bilateral canal, completely restrict to the frontal bone, surrounds the upper half of the orbit. The posterior medial portion of the supraorbital canal continues from the temporal canal.

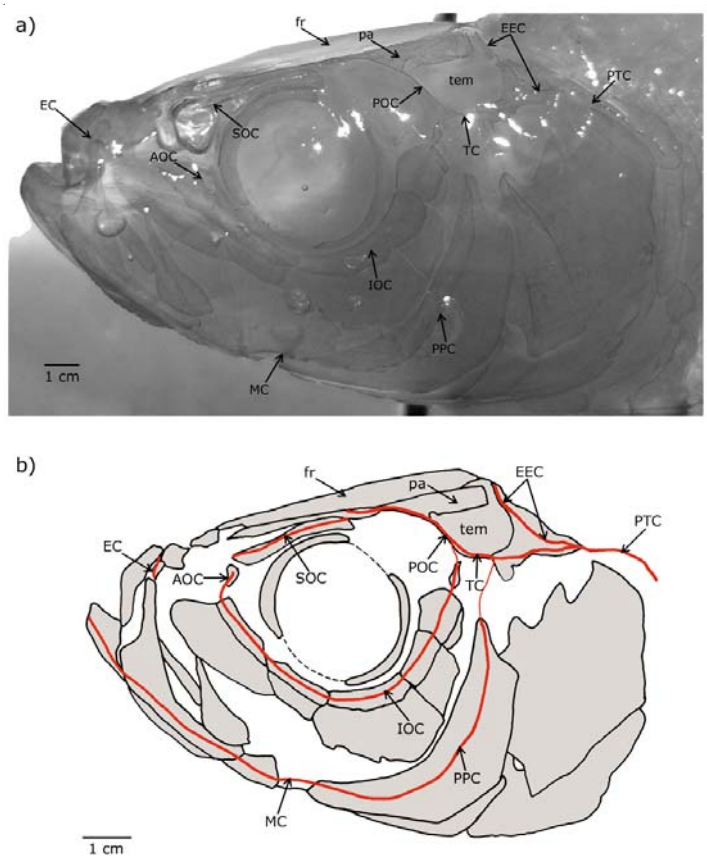

Figure 1. a) Cephalic sensory canals of *Strangomera bentincki.* b) Scheme based on Fig. 1a. AOC, antero orbital canal; SOC, supra orbital canal; POC, postorbital canal; IOC, infraorbital canal; EC, ethmoidal canal; TC, temporal canal; PTC, post temporal canal; PPC, preopercular canal; MC, mandibular canal; EEC, extrascapular canal; fr, frontal bone; pa, parietal bone; tem, temporal bone / a) Canales sensoriales cefálicos de *Strangomera bentincki*. b) Esquema basado sobre la Fig. 1a. AOC, canal antero orbital; SOC, canal supraorbital; POC, canal postorbital; IOC, canal infraorbital; EC, canal etmoidal; TC, canal temporal; PTC, canal post temporal; PPC, canal preopercular; MC, canal mandibular; EEC, canal extraescapular; fr, hueso frontal; pa, hueso parietal; tem, hueso temporal

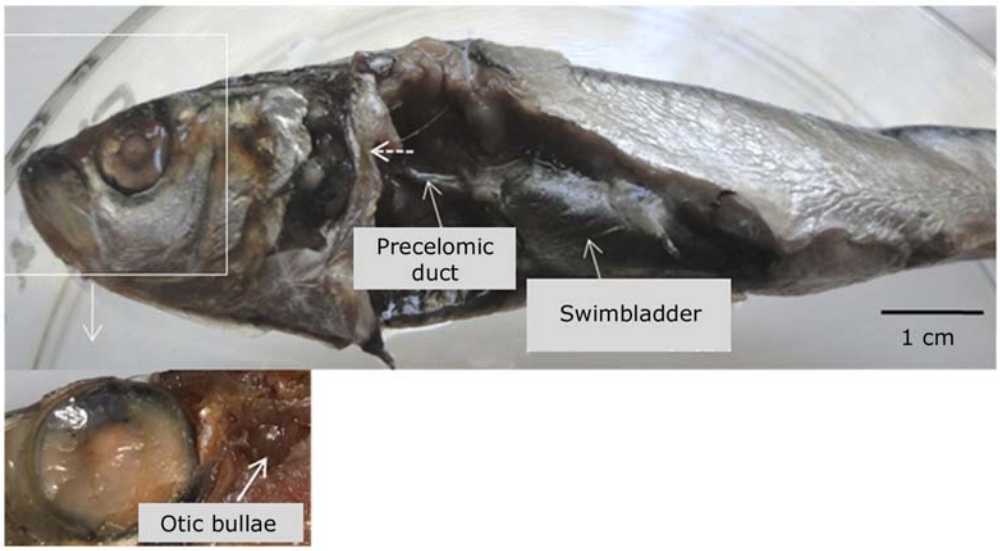

Figure 2. Dorsal view of the swimbladder and pre-celomic ducts in *Strangomera bentincki*. The segmented arrow indicates entry of the pre-celomic ducts towards the cranial region. In the low box there is an approximation of the post orbital region and the location of the otic bullae / Vista dorsal de la vejiga gaseosa y su conducto pre-celómico en *Strangomera bentincki*. La flecha segmentada, señala la entrada del conducto pre-celómico hacia la región craneana. En el recuadro inferior un acercamiento de la región post orbital y la ubicación de la bula ótica

Infraorbital canal (IOC): bilateral canal that borders the upper inside region of the orbit, antero dorsally connects with the anterorbital canal. It is located in the dorsolateral portion of the supraorbital bones.

Anteroorbital canal (AOC): bilateral canal, small, located in front of the eye. It extends upwards and laterally in the orbital region.

Postorbital canal (POC): bilateral canal, that originates from the supra orbital canal, between the division of the parietal and the temporal canal.

Preopercular canal (PPC): it is the longest of all the observed canals in this species.

Bilateral canal, and bordering the preopercular bone. This canal continues anteriorly towards to the lower jaw, where it continues as the mandibular canal.

Mandibular canal (MC): bilateral canal, is situated at the lower jaw, including the dentary bone.

Ethmoidal canal (EC): short canal, is located between the nasal and premaxillar bones.

Postemporal canal (PTC): long canal and contact the posteriomedial region of temporal canal and extends over the start of the operculum bone.

Temporal canal (= pterotic canal) (TC): canal situated behind of the anterior extension of the infraorbital canal. Its anterior margin contacts the sphenotic and the lateral wing of the frontal bone.

Extrascapular canal (EEC): short canal, located over to the temporal canal. This canal contacts the posteromedial region of the temporal canal. The EEC presents a superior shorter branch towards the temporal superior edge and a longer one that goes down by the temporal bone edge and extends towards the branch were the postemporal channel begins.

Associated structures to the cephalic sensorial system: swimbladder and otic bullae

These structures are common to almost all modern clupeormorphs. In the dissected specimen, the pre-coelomic duct from the normal elliptical shape, mediun size swimbladder, that penetrates the skull through the exoccipital bone and expands inside the cranium, forming two bony capsules (otic bullae) in the prootic and also in the pterotic bones (Fig. 2).

The branched and narrow cephalic sensory canals observed in *S. bentincki*, it is a primitive condition of the Clupeiformes and reflects the complexity of these mecanosensorial structures (Webb 1989).

Despite the limited literature, we were able to compare the sensory canals of *S. bentincki* with other clupeomorphs, such as *Clupea pilchardus* and *Denticeps clupeoides* (Wohlfahrt 1937, Di Dario & De Pinna 2006),

being *C. pilchardus* phylogenetically a taxon closer to *S. bentincki* (Lavoué *et al.* 2007). In both cases, the main difference is in the shape and size of the supraorbital, anterorbital, preopercular, mandibular, ethmoidal and postemporal canals. While comparing *Strangomera bentincki* with *C. pilchardus*, is noted that the supraorbital canal is shorter, the anterorbital canal is smaller, preopercular canal is more rounded in our specimens, and the mandibular canal is shorter than that observed in *C. pilchardus*. In the case of *D. clupeoides*, the main difference is the presence of a lateral line in the trunk, an L-shaped preopercular canal and larger supraorbital, anterorbital, postorbital and ethmoidal canals.

It is possible that the presence of these sensory structures have maintained their cephalic position on the possibility of development into the trunk, because they are closer to the brain, sensory and behavioral command unit and transmission of impulses, as well as the fast and sudden movements, that probably has been decisive in the schooling survival to predator in attacks, which may have been submitted in its long evolutionary step (Webb 1989).

An important structure associated to this complex cephalic sensory system, is the swimbladder. This structure can be classified according to its shape (normal to elliptic, medially compressed, anteriorly compressed and posteriorly compressed) and it size (small, medium, big, distended) (Blaxter & Batty 1990, Ganias *et al.* 2015). It is generally accepted that the herring swimbladder plays a minor role in buoyancy and that it functions mainly as a reservoir for the acoustic system (Blaxter 1985, Blaxter & Batty 1990). The other associated structure of the cephalic sensory system in clupeids is the otic bullae, that together with the head lateral line also stimulate the lateral line neuromasts (White & Blaxter 1989). Therefore, these two structures, along with the cephalic canals, vests the individual with great sensitivity to the environment surrounding it and allow it to respond to potential attacks from predators. It is important to carry out more morphological studies and a complete description of the types of swimbladders as well as the otic bullae, to obtain a complete perspective of the cephalic sensory structures found in Chilean clupeids, facilitating comparisons among taxa. It is important to emphasize that the cephalic sensory canals are an important aspect in the phylogenetic study of fishes (Arratia 1996, Webb 2013) and their configurations, could show taxonomic differentiation among species and eventually constitute elements for systematic and evolutionary analysis. Unfortunately, the scarce literature in Chilean Clupeiformes, especially in *S. bentincki*, makes it difficult to perform better morphological comparions of these sensory structures.

It is mandatory to corroborate with more biological samples if other species of the region also have patterns that allow its use in taxonomy, systematic, ethology, physiology and other aspects and advance in the knowledge of such sensory structures.

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Literature cited

Aranis A, R Meléndez, G Pequeño & F Cerna. 2007. *Sprattus fuegensis* en aguas interiores de Chiloé, Chile (Osteichthyes: Clupeiformes: Clupeidae). Gayana 71(1): 102-113.

Arratia G. 1996. Basal teleosts and teleostean phylogeny. PhD Thesis, Department of Historical Geology and Paleontology, Institute of the Earth Science, Uppsala University, Uppsala, 318 pp.

Blaxter JHS. 1985. The herring: A successful species? Canadian Journal of Fisheries and Aquatic Sciences 42: 21-30.

Blaxter JHS & RS Batty. **1990**. Swimbladder 'behaviour' and target strenght. Rapports et Procès-Verbaux des Réunions / Conseil Permanent International pour l'Exploration de la Mer 189: 233-244.

de Buen F. 1958. Peces de la superfamilia Clupeoidae en aguas de Chile. Revista de Biología Marina 8(1-3): 83-110.

Di Dario F. 2004. Homology between the *recessus lateralis* and cephalic sensory canal, with the proposition of additional synapomorphies for the Clupeiformes and the Clupeoidei. Zoological Journal of the Linnean Society 141: 257-270.

Di Dario F & MC De Pinna. 2006. The supratemporal system and the pattern of ramification of cephalic sensory canals in *Denticeps clupeoides* (Denticipitoidei, Teleostei): additional evidence for monophyly of Clupeiformes and Clupeoidei. Papéis Avulsos de Zoologia, São Paulo 46(10): 107-123.

Ganias K, S Michou & C Nunes. 2015. A field based study of swimbladder adjustment in a physostomous teleost fish. PeerJ 3: 2-14.

Grande L. 1985. Recent and fossil clupeomorph fishes with material for revision of the subgroups of clupeoids. Bulletin of the American Museum of Natural History 181: 231-372.

Greenwood PH. 1968. The osteology and relationships of the Denticipitidae, a family of clupeomorph fishes. Bulletin of the British Museum, Natural History, Zoology 16: 215-273.

Kasumyan AO. 2003. The lateral line in fish: structure, function, and role in behavior. Journal of Ichthyology 43(Suppl. 2): S175-S213.

Lavoué S, M Miya, K Saitoh, NB Ishiguro & M Nishida. 2007. Phylogenetic relationships among anchovies, sardines, herrings and their relatives (Clupeiformes), inferred from whole mitogenome sequences. Molecular Phylogenetics and Evolution 43: 1096-1105.

Nelson G. 1972. Cephalic sensory canals, pitlines, and the classification of esocoid fishes, with notes on galaxiids and other teleosts. American Museum Novitates 2492: 1-42.

Ohshimo S. 1999. Development of the cephalic lateral line nerves of the Japanese anchovy, *Engraulis japonicus*. Bulletin of the Seikai National Fisheries Research Institute 77: 1-10.

Silva S & G Pequeño. 2007. Los peces Clupeiformes del litoral valdiviano (Chile): clave de reconocimiento y comentarios (Pisces: Osteichthyes). Revista de Biología Marina y Oceanografía 42(3): 357-363.

Stephens RR. 2010. A description of the cephalic lateralis system of *Anchoa mitchilli* (Valenciennes) (Clupeomorpha: Engraulidae) with identification of synapomorphies for the Engraulidae. Proceedings of the Biological Society of Washington 123(1): 8-16.

Taylor R. 1967. An enzyme method of clearing and staining small vertebrates. Proceedings of the United States National Museum 122(3596): 1-17.

Tracy HC. 1920. The clupeoid cranium in its relation to the swimbladder diverticulum and the membranous labyrinth. Journal of Morphology 33: 439-483.

Webb J. 1989. Gross morphology and evolution of the mechanoreceptive lateral line system in teleosts fishes. Brain Behaviour Evolution 33: 34-53.

Webb J. 2013. Morphological diversity, development, and evolution of the mechanosensory lateral line system. In: Coombs S, H Bleckmann, RR Fay & AN Popper (eds). The lateral line system, pp. 17-72. Springer Handbook of Auditory Research 48, Springer Science, New York.

Whitehead PJP. 1985. FAO species catalog. Clupeoid fishes of the world (suborder Clupeoidei). Part 1 - Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis 125(7), pt. 1: 1-303.

Whitehead PJP & HS Blaxter. 1989. Swimbladder form in clupeoid fishes. Zoological Journal of the Linnean Society 97(4): 299-372.

Wohlfahrt TA. 1937. Anatomische untersuchungen über die seitenkanale der sardine (*Clupea pilchardus* Walb.). Zeitschrift für Morphologie und Ökologie der Tiere 33: 381-411.

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