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Short Communication

The cephalic lateral line system of the pelagic fish *Normanichthys crockeri* (Clark, 1937) (Pisces: Normanichthyidae) from southern Chile

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ABSTRACT. The cephalic lateral line system of the Normanicthyidae family monotypic species, *Normanichthys crockeri* from Corral Bay, Chile was studied. *N. crockeri* is a small, schooling and pelagic fish from the southeast Pacific coast between Chimbote, Perú and Mocha Island, Chile. *Normanichthys* displays a cephalic latero sensorial system constituted by pores and canals. The pores are in six cephalic zones: five preopercular pores (pr.p), five mandibular pores (m.p), three supraorbital pores (so.p), eight infraorbital pores (io.p), three postorbital pores (po.p), three supratemporal pores (st.p) and only one coronary pore (c.p). The high number of pores distributed along the anterior, middle and posterior zones of the orbit stands out, making it a quite sensitive area. In the jaw, five elongated pores join those present in the preoperculum that, along with the rest of the cephalic pores in the supraorbital, supratemporal and postorbital regions make yet another area sensitive to the water flow. These pores are connected with eight narrow, continuous and simple canals: preopercular canal (PR), mandibular canal (MD), supraorbital canal (SO), infraorbital canal (IO), supratemporal canal (ST), otic canal (OT), post-otic canal (PO) and temporal canal (T). This type of canal is the most common pattern found among bony fishes and is designed to respond maximally to water flow velocity along the axis of the canal. These results will help understand part of the cephalic sensorial lateral line biology of this species, which has been barely considered in the ichthyological literature.

Keywords: *Normanichthys crockery*; mote sculpin; lateral line; morphology; southeastern Pacific

The mechanosensory system of the lateral line is a group of structures present in the cephalic region and in the trunk of fishes, connected to the eighth pair of cranial nerves and involved in behaviours like feeding, swimming, prey and predator detection, rheotaxis, schooling, intraspecific communication and wave source location (Engelmann *et al.*, 2002; Kasumyan, 2003; Modgans *et al.*, 2003, 2004). The mechanosensory system has also played an important role in the fields of comparative neuroanatomy and development biology (Webb, 2014).

The cephalic lateral line canals of bony fishes are contained in dermal skeletal elements of the cranium related to some bones like the preopercular, infraorbital, supraorbital and mandibular bones among others, forming the cephalic lateral line canal system (Webb, 1989, 2014; Gibbs, 2004). These canals communicate with the exterior through pores located on the epidermis and in some species, can be observed in plain sight (Webb, 1989; Kasumyan, 2003; Gibbs, 2004).

The mechanosensory system of the lateral line in the Scorpaeniformes order, has been studied in taxa like Liparidae (Chernova & Stein, 2004; Lanoo *et al.*, 2009), Cottidae (Jones & Jansen, 1992; Telcean *et al.*, 2005; Coombs & Grossman, 2006), Hexagrammidae (Wonsettler & Webb, 1997) and Normanichthyidae (Mandrytsa, 1993). In Chile, a representative from the Scorpaeniformes is *Normanichthys crockeri* (Clark, 1937), a monotypic species from the Normanichthydae family, an endemic, pelagic fish from the southern Pacific, it has a small size and a geographical extension that goes from Perú to Mocha Island in Chile (Vegas & Pequeño, 1993; Yabe & Uyeno, 1996; Velez *et al.*, 2003). While there are many Scorpaeniformes fishes, mainly from the *Sebastes* genera that form schools, demersal and mainly benthonic, it is rare to pelagic fishes from this order, more so epipelagic (Landaeta *et al.*, 2010; Ralston *et al.*, 2013). In the southeastern Pacific, *N. crockeri* is the only epipelagic schooling Scorpaeniform that usually can be seen along with

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other fishes like the common sardine (*Strangomera bentincki*) or the anchovy (*Engraulis ringens*) (Arrizaga *et al*., 1993; Landaeta *et al*., 2010). These three species are endemic of the southeastern Pacific. Commonly appearing in dragnet catches, are registered in the Chilean fish landings statistics (SERNAPESCA, 2014).

The cephalic lateral line of *Normanichthys* has been considered in both systematic and phylogenetic studies, considering some bony structures (Yabe & Uyeno, 1996; Mandrytsa, 1993). However, except for the work done by Mandrytsa (1993), where the latero sensorial system of the Scorpanoidei superorder was analyzed for systematic purposes, there is no piece of literature in Chile that studies the cephalic sensorial system in *N. crockeri*. Consequently, due to this lack of information regarding the description of the latero sensorial system of *N. crockeri* and the need of data about its biology, this study describes, for the first time, the cephalic lateral line system of the species in individuals from southern Chile. This work aims to describe the trajectory, shape, quantity, and arrangement of the canals and pores present in said system. The results obtained during this study will help understand one aspect of the biology of this monotypic species, barely known and studied in the literature.

Five specimens of *N. crockeri* were studied, caught using a dragnet approximately three miles east from Corral Bay (39°52’S, 73°26’W, Valdivia, Chile), all measuring between 81.2 and 105.9 mm of total length. The standard length varied between 69.3 and 92.4 mm whereas the head length varied between 23.2 and 27.1 mm. This study consisted of a macroscopic observation of the cephalic pores aided by a binocular magnifying glass, recording the form and quantities of the pores in the different regions of the head (Fig. 1). In the following stage of this study, the specimens were diaphanized using the same technique as in Taylor (1967) for the canals to be easily described and schematized (Fig. 2).

The cephalic lateral line canals nomenclature follows the criteria described by Webb (1989): PR: preopercular canal, MD: mandibular canal, SO: supraorbital canal, IO: infraorbital canal, OT: otic canal, PO: postorbital canal, ST: supratemporal canal, T: temporal canal. The counting of the cephalic pores was made from the anterior cephalic region to the caudal end.

In *Normanichthys* specimens, the cephalic latero sensorial system was constituted by canals and pores. The pores were located over the epidermis and connected with the bones in which the canals of the latero sensorial system lie (Fig. 1). The following pores can be observed:

- Preopercular pores (pr.p), there were five: two (pr.p 1, 2) over the lower portion of the preoperculum curvature, and the last three pores (pr.p 3, 4, 5), were arranged in a straight line to the edge (the upper portion of the preoperculum) of the same bone (Fig. 1a).
- Mandibular pores (m.p), there were five elongated pores arranged on the jaw, from the symphysis (m.p 1) to half the level of the eye (m.p 5) (Fig. 1a). The branches from both sides of the jaw (right and left) intercept at the symphysial pore (m.p 1) level.
- Preopercular mandibular pores (pm.p), constituted by the mandibular and preopercular pores. The first preopercular pore (pop 1) reached the last mandibular pore at the level of the fifth mandibular pore (m.p 5) (Fig. 1a).
- Supraorbital pores (so.p), there were three pores: one (so.p 1) located near the upper anterior nasal opening, another one (so.p 2) located between the nasal openings (anterior and posterior opening) and the last one (so.p 3) located in the interorbital space, near the supraorbital edge (Fig. 1b).
- Infraorbital pores (io.p), there were eight of them, from which three (io.p 1, 2, 3) were located on the anterior region of the orbit, three underneath the orbit (io.p 4, 5, 6) and two (io.p 7, 8) on the posterior region of the orbit (Fig. 1a).
- Postorbital pores (po.p), there were three (po.p 1, 2, 3), starting behind the eye and continuing in a straight line towards the beginning of the preoperculum (Fig. 1a).
- Coronary pore (c.p), the only pore (c.p 1) located in the interorbital space, at the same level of the posterior edge of the orbits (Fig. 1b).

The pores were associated with the canals of the cephalic lateral line. In this species, the canals are the narrow, simple and continuous type (Fig. 2). It is possible to assert the presence of eighth canals: the preopercular canal (PR), the mandibular canal (MD), the supraorbital canal (SO), infraorbital canal (IO), otic canal (OT), post-otic canal (PO), supratemporal canal (ST) and temporal canal (T).

- Preopercular canal (PR), ran along the preoperculum bone, its lower end joined with the posterior and last end of the mandibular canal, forming the preoperculo-mandibular canal (PRMD) (Fig. 2a).
- Mandibular canal (MD), located over the lower jaw, it extended from the anterior part of that bone, passing through the articular, angular and retroarticular bones, until almost reaching the lower end of the preoperculum where they form the PRMD (Fig. 2a).

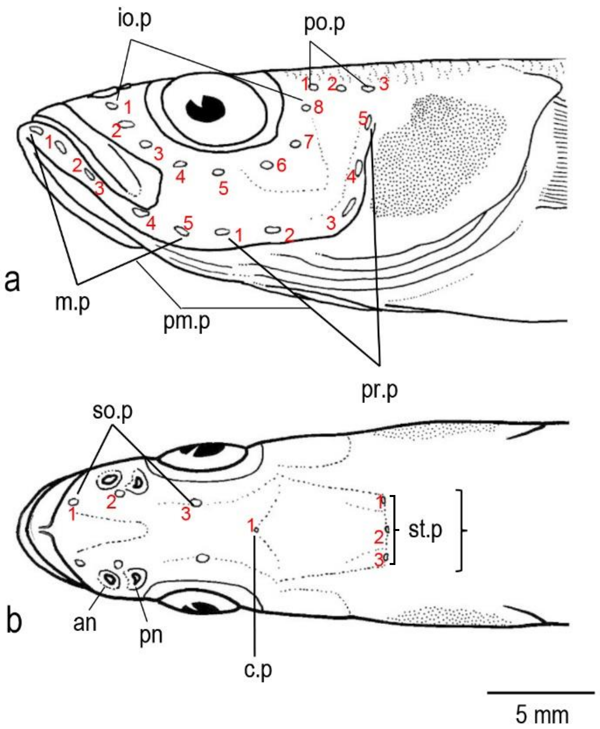

Figure 1. Arrangement of the cephalic pores in *Normanichthys crockeri*. a) Lateral view: mandibular pores (m.p 1, 2, 3, 4, 5); infraorbitals pores (io.p 1, 2, 3, 4, 5, 6, 7, 8); preopercular pores (pr.p 1, 2, 3, 4, 5); preopercular mandibular pores (pm.p); and post orbital pores (po.p 1, 2, 3), b) dorsal view: supraorbitals pores (so.p 1, 2, 3); coronary pore (c.p 1); supratemporal pores (st.p 1, 2, 3); an, anterior nasal opening; and, pn, posterior nasal opening.

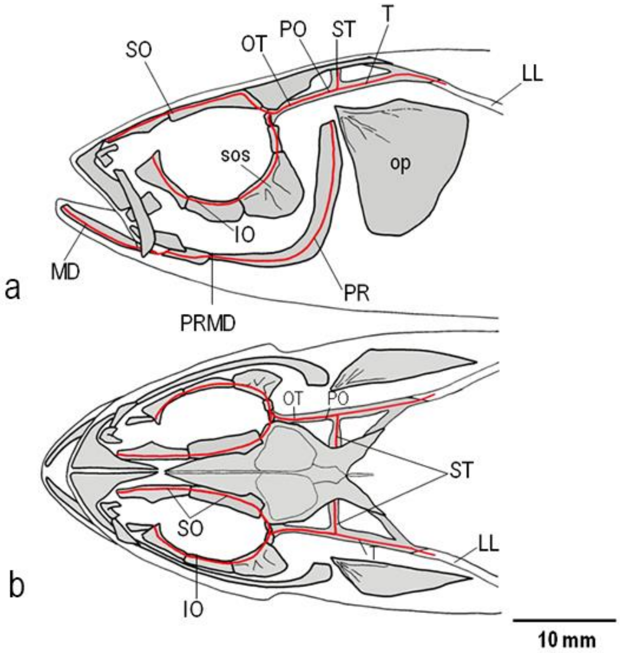

Figure 2. The trajectory of the lateral line cephalic canals in *Normanichthys crockeri*. a) Lateral view. MD: mandibular canal, PR: preopercular canal, PRMD: preoperculo mandibular canal, IO: infraocular canal, SO: supraorbital canal, OT: otic canal, PO: post-otic canal, ST: supratemporal canal, T: temporal canal, SOS: suborbital stay, op: operculum, LL: lateral line, b) dorsal view. IO: infraocular canal, SO: supraocular canal, T: temporal canal, ST: supratemporal canal, OT: otic canal, PO: post-otic canal, LL lateral line.

- Supraorbital canal (SO), it began in the anterior nasal opening and continued towards the postorbital region, where it connected with the posterior end of the infraorbital canal and with the beginning of the otic canal (Figs. 2a-b).
- Infraorbital canal (IO), located underneath the orbit, it began in the anterior nasal opening and ended just behind the eye, where it connected with the otic and supraorbital canals (Figs. 2a-b).
- Otic canal (OC), located behind the eye. It was connected anteriorly with the SO and the IO. In its trajectory, it joined the post-otic canal (PO) (Figs. 2a-b).
- Post-otic canal (PO), located right next to the OC, above the preoperculum and the upper end of the operculum. It was connected with the supratemporal and temporal canals (Figs. 2a-b).
- Temporal canal (T), located next to the PO, it was connected to the ST and the beginning of the lateral line of the trunk (Figs. 2a-b).
- Supratemporal canal (ST), bounded both of the supratemporalis canals (commissural canals) transversally. This canal connected both the left and right branches of the cephalic lateral system, except for the preoperculum-mandibular canal (Figs. 2a-b).

The latero sensorial system of *N. crockeri* is constituted by a system of narrow and simple canals, the most common type of canals among bony fishes and its designed to respond to the slightest changes in the velocity of the water flow along the axis of the canal. This canal type is filled with a water-like fluid, contains smaller neuromasts and is usually bony (Gibbs, 2004). The presence of this type of canal has a direct relationship with the pelagic condition of the fish and its schooling behavior that enables *Normanichthys* to move more effectively since it is known to be a poor swimmer (Vegas & Pequeño, 1993). This statement is supported by the presence of some morphological characteristics such as the absence preopercular spines and the lateral compression of the body, which belongs to a typical hydrodynamic model of nektonic fishes (Aleyev, 1977; Vegas & Pequeño, 1993). The general body structure in a nektonic fish is determined on the whole by the development of a complex of adaptations, functionally associated with decreasing hydrodynamic resistance and increasing the capacity for active propulsion in the mass of water with the minimum expenditure of energy (Aleyev, 1977). In this regard, it has been observed that those individuals with a total length greater than 15 cm are unable to neutralize the oceanic currents (Vegas & Pequeño, 1993). For this reason, the taxa with the described swimming conditions form schools, which allows them to minimize water friction, avoiding predators and migrating more efficiently, traveling long distances (Aleyev, 1977).

Additionally, the eyes of *Normanichthys* are close to the longitudinal axis of the body, which allows better and symmetrical eyesight, simplifying the information acquisition from the surroundings of the fish (Vegas & Pequeño, 1993).

The infraorbital region presents the highest quantity of pores, distributed in the anterior, medium and posterior parts of the orbit, making it a very sensitive region, which is consistent with the size of the eye and its position. In the jaw, five elongated pores join those present in the preoperculum, that along with the rest of the cephalic pores in the supraorbital, supratemporal and postorbital regions make yet another area sensitive to the water flow. In this regard, this sensory system is concentrated in locations where changes in water pressure are the greatest while in motion and, some authors suggest that the arrangement of the lateral line system reflects the hydrodynamic information available to the fish during swimming (Windsor & McHenry, 2009; Ristroph *et al.,* 2015). Ristroph (2015), states that the branching of the lateral line in the head could be utilized to collect three-dimensional information or to isolate the sensation of the auto-generated fluctuations due to the propulsion of the caudal fin. These authors suggest that the disposition of the lateral line system reflects the hydrodynamic information available to the fish while swimming. Therefore, the cephalic canals of the lateral line would serve as a "hydrodynamic antenna" placed over the surface of the body and configurated to detect changes in pression.

The taxonomic status of *N. crokeri* has been subjected to changes throughout history; ichthyologists formerly related this species with the Cottoidei suborder due to some myological and osteological characters (Vegas & Pequeño, 1993; Yabe & Uyeno, 1996). Consequently, Clark (1937) deemed necessary to classified it in a new and monotypic family and genera, later complemented by Norman (1938), who underlined some osteological aspects of the species, proposing its classification in the Cottidae family, from which it might be a primitive member.

Moreover, from the osteological and sensorial point of view, it is considered that the connection of the third infraorbital bone to the preoperculum, and the presence of a tabular bone for the occipital sensorial canal over the parietal bone (Yabe & Uyeno, 1996), constitute a substantial difference between Cottidae and Normanichthyidae. The latter has a suborbital stay and lacks a bony parietal structure which holds the sensorial canal (Imamura & Yabe, 2002).

In general, the information about the mechanosensory biology of *N. crockeri* is scarce. Since this species has an important role in the coastal pelagic food chain (Vegas & Pequeño, 1993; Silva *et al.,* 2014), is of vital importance, to know some aspects of the sensorial biology of this species that would help to understand its behaviour when confronted with predators or a potential environmental threat and its survival capacity. The obtained results strengthen the knowledge of the sensorial biology in this species, which will be crucial for further comparative studies with other members of the Scorpaeniformes order.

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