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Ecomorphological patterns of the *lapilli* of Paranoplatense Siluriforms (South America)

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ABSTRACT

The morphology and morphometry of *lapillus* otoliths were studied in bottom frequenters, intermediate and benthonic fishes. The shape, margins and type of *sulcus* of 3 groups of otoliths from 19 species were analyzed: group 1 (bottom frequenters, 11 spp), group 2 (intermediate, 5 spp) and group 3 (benthonic, 3 spp). The indices EL (maximum width of the *lapillus* (WOL)/maximum length of the *lapillus* (LOL) %) and *S* (*sulcus* area/otolith area %) were calculated for each species.

The *lapilli* of bottom frequenters and intermediate groups showed, in their ventral face, similar morphological features, high shape variability (oblong shape, elongated shape and quadrangular shape) and a *sulcus* surface that represents 16–34% of otolith surface. The *lapilli* of the benthonic group are globosal or rounded with a *sulcus* surface that represents less than 12% of otolith surface.

Statistical analyses showed significant differences in the EL and *S* indices between the benthonic group and the other two groups, but there were no differences between the otoliths of the bottom frequenters and intermediate groups. EL and *S* values could be used to characterize the *lapilli* of the paranoplatense fish and could be considered a useful tool for fish ecology studies.

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1. Introduction

Neotropical fishes richness includes 4475 valid species (representing 71 families). The order Siluriforms contributes with 1648 species (15 families) (Reis et al., 2003).

The Paranoplatense zoogeographical province is the widest ichthylogical region in Argentina, occupying approximately the 75% of the country and it has the largest biodiversity (Menni, 2004; López and Miquelarena, 2005; López et al., 2008). In this region we find 83.5% of the Siluriform species from Argentina (162 out of 194) (López and Miquelarena, 2005; Liotta, 2006). Siluriforms, are predated by ichthiophagous birds and water mammals, such as *Lutra longicaudis* (Olfers, 1818) (vulnerable species) and *Pteronura brasiliensis* (Gmelin, 1788) (endangered species) (Parera, 1992, 1996).

The fish inner ear comprises three otolith systems with specific hair orientation patterns. These are semicircular canals (anterior, posterior and horizontal) and three otolithic end organs (saccule, lagena and utricle), which have related otoliths: *sagittae*, *asterisci* and *lapilli*. In particular in ostariophysian groups the *lapilli* is usually larger than the other two and appear to be more engaged in the sense of posture (Schellart and Popper, 1992; Assis, 2005) and have a very homogeneous structure among all vertebrates (Cordier and Dalcq, 1954; Popper and Coombs, 1982).

Siluriform fish use the water column in different forms and these uses determine different ecological groups. These fish species have developed a wide range of feeding strategies, which allow them to utilize food resources in a variety of habitats (Abes et al., 2001; Fugi et al., 2001; Rossi, 2001; Viana et al., 2006; Fagundes et al., 2008).

Otoliths allow the analysis of different aspects of fish biology and their environment (Morales-Nin, 1987; Gauldie, 1993; Torres et al., 2000; Volpedo and Echeverría, 2003). Environmental factors (Aguirre and Lombarte, 1999; Torres et al., 2000; Gauldie and Crampton, 2002; Volpedo and Echeverría, 2003; Volpedo et al., 2008), feeding habits (Nonogaki et al., 2007), ontogeny (Volpedo and Echeverría, 1999; Tombari et al., 2005), physiology, such as the hearing capabilities associated with specialization in acoustic communication (Popper and Fay, 1993; Paxton, 2000; Lombarte

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and Cruz, 2007), and phylogeny (Assis, 2003, 2005; Nolf and Tyler, 2006), could affect the morphology, the morphometry and the microstructure of otoliths (Campana et al., 1995; Volpedo and Fernández Cirelli, 2006; Volpedo et al., 2007).

The aim of the present paper is to analyze whether the morphological features of Siluriform fish *lapilli* could be associated with water column use.

2. Materials and methods

A total 462 *lapilli* were sampled from 19 fish species (Table 1) obtained from commercial and sport fisheries from paranoplatense rivers and lakes (Río de La Plata, Río Paraná, RíoUruguay, Río Salado, Río Sarmiento, Río Luján, Laguna de Chascomús, Laguna de Lobos, Laguna de Monte, Punta Lara, Santa Fé (Playa Municipal, Boca Cerrada) y Entre Ríos) (Fig. 1).

Fish were assigned to three ecological groups, suggested by Ringuelet et al. (1967): (1) bottom frequenters (inhabit vegetated environments, soft bottom. Usually present well-developed barbels, and a forked caudal fin. They are omnivorous, they feed mainly on molluscs, crustaceans, insects, small fishes and organic matter present in mud bottom. The big catfishes are speedy swimmers while remaining fish of this group are less speed), (2) intermediate (inhabit vegetated environments, dark waters. Their feeding regime is omnivorous, including carrion; they also feed on fruits, insect larvae and aquatic insect adults. They swim to surface to breathe atmospheric air) and (3) benthonic (inhabit slow flowing water courses, with muddy and rocky bottoms, but some inhabit clear and fast water streams. Their body is entirely cover by bony plates, the ventral surface of the body is plane and the dorsal is curved or angled, so the body section is triangled. They have short barbels and an inferior mouth surrounded by wide lips. The feeding regime is detritivore-iliophagus. They usually rested on the substrate clinging by their mouth sucker). The criteria used to separate the fish into these groups were taken from literature: trophic habits, swimming style and habitat (Ringuelet et al., 1967; Ringuelet, 1975; Goulding, 1981; Cordiviola de Yuan and Pignalberi de Hassan, 1985; Burgess, 1989; Mills and Vevers, 1989; COMIP, 1994; Boujard et al., 1997; Le Bail et al., 2000; Hahn et al., 2002; Ferraris, 2003a,b;

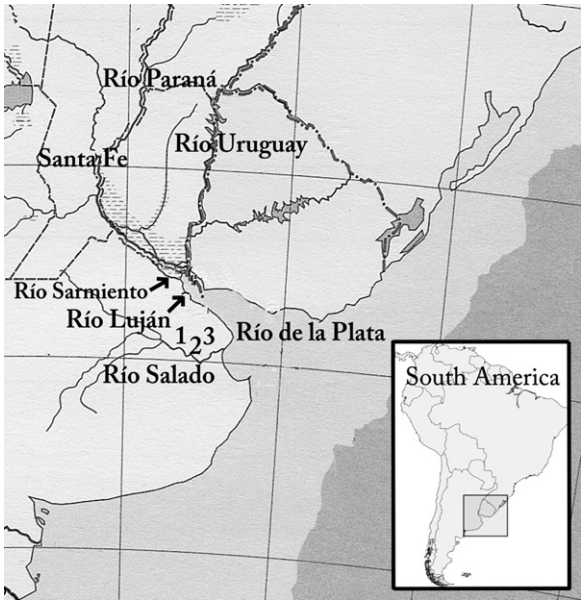

Fig. 1. Map showing the sampling localities. 1 – Laguna de Lobos, 2 – Laguna de Monte, 3 – Laguna de Chascomús.

Table 1
List of the studied species, including sizes, sampling locations and ecotype.

Family/species	*N*	SL	Sampling locations	Ecological group	Author
Auchenipteridae					
Ageneiosus inermis (Linnaeus, 1766)	6	130–440	a, b	Bf	1, 2, 5, 11
*Auchenipterus nuchalis*** (Spix and Agassiz, 1829)	1	108	c	Bf	1, 2, 5, 11
Callichthyidae					
Callichthys callichthys (Linnaeus, 1758)	2	60–110	d	I	1, 2, 14, 16
Corydoras paleatus (Jenyns, 1842)	17	29–63	d, e	I	8, 14, 16
Doradidae					
Pterodoras granulosus (Valenciennes, 1821)	9	294–370	a, f	I	1, 2, 15, 16
Rhinodoras dorbignyi (Kner, 1855)	2	143–160	f	Bf	1, 2, 15
Heptapteridae					
Pimelodella gracilis (Valenciennes, 1836)	13	86–130	f	I	6, 7
Pimelodella laticeps Eigenmann, 1917	53	23–107	e.	I	18, 19
Rhamdia quelen (Valenciennes, 1836)	43	94–320	e, g, h, i	Bf	1, 2, 18
Loricariidae					
Hypostomus commersoni Valenciennes, 1836	12	195–330	b, e, k	B	1, 2, 12
Loricariichthys anus (Valenciennes, 1836)	41	89–445	a, e, h	B	1, 2, 12
Paraloricaria vetula (Valenciennes, 1836)	7	320–422	a, l	B	1, 2, 12
Pimelodidae					
Iheringichthys labrosus Lütken, 1874	9	76–240	a, c, m	Bf	1, 2, 4, 10, 13
Luciopimelodus pati (Valenciennes, 1836)	28	105–970	a, c, f, m, n	Bf (fast)[a]	1, 2, 3, 10, 13
Parapimelodus valenciennis (Lütken, 1874)	127	51–240	a, e, g, m	Bf	1, 2, 9, 10, 13
Pimelodus albicans (Valenciennes, 1840)	49	38–345	a, c, g, j, m	Bf	1, 2, 3, 10, 13
Pimelodus argenteus Perugia, 1891	4	105–150	a, m	Bf	1, 2, 19
Pimelodus maculatus Lacepède, 1803	21	44–235	a, b, o	Bf	1, 2, 4, 13
Sorubim lima (Bloch & Schneider, 1801)	18	24–142	b, c	Bf (fast)[a]	1, 2, 10, 13

** ED not shown because it is only one fish. Sampling locations: (a) Río de la Plata, (b) Punta Lara, (c) Río Paraná, (d) Provincia de Buenos Aires, (e) Laguna de Chascomús, (f) Río Uruguay, (g) Río Salado, (h) Laguna de Lobos, (i) Laguna de Monte, (j) Punta Lara, (k) Entre Ríos, (l) Playa Municipal (Santa Fe), (m) Río Sarmiento, (n) Boca Cerrada (Santa Fe), (o) Río Luján. (1) Ringuelet et al. (1967), (2) Ringuelet (1975) (3) Goulding (1981), (4) Cordiviola de Yuan and Pignalberi de Hassan (1985), (5) Burgess (1989), (6) Mills and Vevers (1989), (7) COMIP (1994), (8) Boujard et al. (1997), (9) Le Bail et al. (2000), (10) Hahn et al. (2002), (11) Ferraris (2003a), (12) Ferraris (2003b), (13) Lundberg and Littmann (2003), (14) Reis (2003), (15) Sabaj and Ferraris (2003), (16) Menni (2004), (17) Andrade and Braga (2005), (18) López et al. (2005), (19) Rosso (2006). SL: standard length (mm); SL: minimum and maximum values. (B) benthonic group, (Bf) bottom frequenters group, (I) intermediate group.

[a] (fast) also found in fast in fast stream rivers.