

Otolith atlas of fish of the Sinos River

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Abstract

Otoliths are calcium carbonate structures located in the inner ear of fish; they are responsible for hearing and balance. The inner ear has three pairs of otoliths: the *lapilli*, the *sagittae* and the *asterisci*. The *sagittae* otoliths are the largest and their format is species-specific. Because of their composition, otoliths can resist to the digestive tract of ichthyophagous species, and they can be used as an important tool for identifying species of fish found in stomach contents. The purpose of this work is to provide a photographic guide of the *sagittae* otoliths of the main fish species from the Sinos River. This atlas consists of photographs of the *sagittae* otoliths of 36 species belonging to 15 families distributed in five orders.

Keywords: photographic guide, *sagittae*, identification.

Atlas de otólitos de peixes do Rio dos Sinos

Resumo

Otólitos são estruturas formadas por cristais de carbonato de cálcio, localizadas no labirinto do ouvido interno dos peixes. São responsáveis pela audição e pelo equilíbrio. O ouvido interno possui três pares de otólitos, os *lapilli*, os *sagittae* e os *asterisci*. Os denominados *sagittae* são os maiores e seu formato é espécie-específico. Devido a sua composição os otólitos conseguem resistir ao trato digestivo das espécies ictiófagas, dessa maneira podem ser empregados como uma importante ferramenta para a identificação de espécies de peixes em trabalhos com conteúdos estomacais. O objetivo deste trabalho é a disponibilização de uma referência visual dos otólitos *sagittae* das principais espécies de peixes do Rio dos Sinos, para que possam servir de base para trabalhos com conteúdos estomacais de espécies ictiófagas. Este atlas é composto de fotografias dos otólitos *sagittae* de 36 espécies de 15 famílias distribuídas em cinco ordens.

Palavras chave: guia fotográfico, *sagittae*, identificação.

1. Introduction

Otoliths are paired structures composed of organic matter and calcium carbonate crystals, especially in the form of aragonite. These structures are located in the membranous labyrinth in the inner ear of fishes and are responsible for sound detection and maintenance of balance (Lecomte-Finiger, 1999; García et al., 2004; Payan et al., 2004; Popper et al., 2005).

The inner ear consists of three pairs of chambers, each containing an otolith. The otolith called *lapilli* occupies the utricular vestibule, the *sagittae* occupies the saccular and the *asterisci* the lagenar vestibule (Secor et al., 1991; Gomiero and Braga, 2007). Each pair is different in shape and appearance, and in most adult fish the *sagittae* are larger and have the largest morphological variability (Campana, 2004; Tuset et al., 2008).

Otoliths are formed from a primordial secreted by the inner ear, and are usually the first calcified structure formed during ontogenesis (Morales-Nin, 2000; Wright et al., 2002). The formation involves rhythmic variations in the deposition and size of the organic matrix fibre, which results in the formation of concentric layers of variable thickness

(Morales-Nin, 2000). These layers alternate in opaque and hyaline layers, representing periods of fast growth and slow growth, respectively; in temperate zones a pair of these layers consists of a year, and this set of layers is called *annulus*, and it is used for the age determination in years (Wright et al., 2002).

The characteristics, shape and growth pattern of otoliths are highly species specific and very similar between individuals (Frost, 1981; Hunt, 1992; Anguirre and Lombarte, 1999). Their chemical composition and microstructure are directly related to environmental conditions, so in addition to the identification of different species it is possible to differentiate between stocks (Lecomte-Finiger, 1999).

Furthermore, otoliths can resist the passage through the digestive tract of ichthyophagous species because of their low degradability. Thus they have been used as an important tool for studies of stomach contents (Frost, 1981; Gomiero and Braga, 2007).

In Brazil there are only otolith catalogs of marine fish, such the work of Correa and Vianna that in 1992/93 described the otoliths of the family Scianidae from the

coast of Paraná. The same study lists only five previous studies of isolated morphological descriptions. In 1995 Lemos et al. (1995a, b), published two catalogs, which describe the otoliths of the family Engraulidae and Cupleidae, both of the coast of Paraná.

The purpose of this work is to provide a photographic guide of the *sagittae* otoliths of the most common fish species from the Sinos river. The intention is to provide a visual reference which may serve as basis for studies of stomach contents of ichthyophagous species.

2. Materials and Methods

The fish used in this investigation were sampled in different projects of the Laboratory of Fish Ecology - UNISINOS. All the fish were captured in the Sinos River by electrofishing or gill nets (meshes 15 mm to 60 mm) between the years of 2006 and 2007. All individuals were measured (standard length, SL), weighed and stored on ice until the removal of otoliths. Only the pair of *sagittae* was removed.

After removal, the otoliths were washed in water and stored in glass tubes that had remained open for about 15 days to ensure that the otoliths completely dried.

Otoliths were measured (otolith length - OL) and photographed in pairs in a way that both sides were visible. The photographs were taken with a Leica Stereo Microscope attached to a video camera, connected to a computer with the image analysis program Leica Application Suite v3.7.

3. Results

In this work we photographed the otoliths of 36 species from 15 families distributed in five orders. Four of these species do not belong to the native fish community of the Sinos river basin. Two are exotic (*Micropterus salmoides* and *Oreochromis niloticus*), one is invasive (*Pachyurus bonariensis*) and another one allochthonous (*Piaractus mesopotamicus*) (Leal et al., 2009).

Characiformes

Anostomidae (Figure 1 and 2)

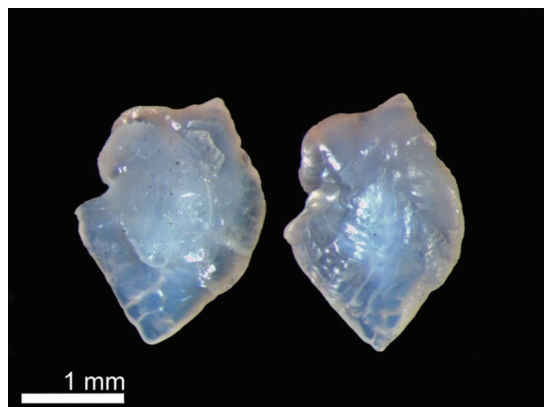


Figure 1. *Sagitta* otoliths of *Leporinus obtusidens* (Valenciennes, 1837) (Fish Length= 18 cm; Otolith Length= 2.6 mm).

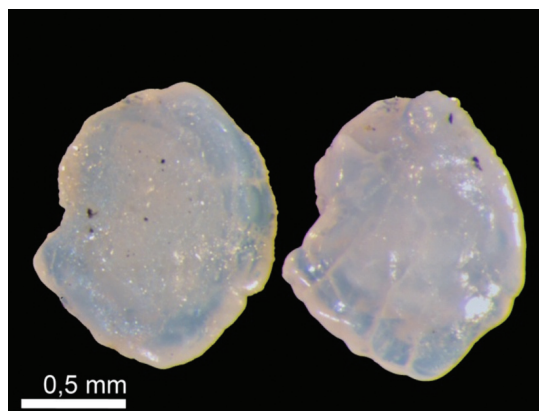


Figure 2. *Sagitta* otoliths of *Schizodon jacuiensis* (Bergmann, 1988) (FL= 7.8 cm; OL= 1.46 mm).

Characidae (Figure 3-10)

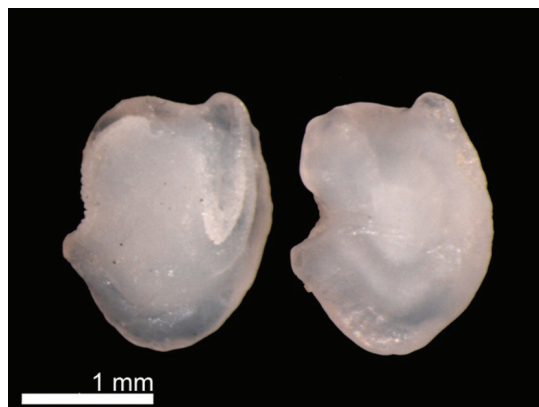


Figure 3. *Sagitta* otoliths of *Astyanax fasciatus* (Cuvier, 1819) (FL= 11.4 cm; OL= 1.97 mm).



Figure 4. *Sagitta* otoliths of *Astyanax jacuhiensis* (Cope, 1894) (FL= 9.4 cm; OL= 1.88 mm).

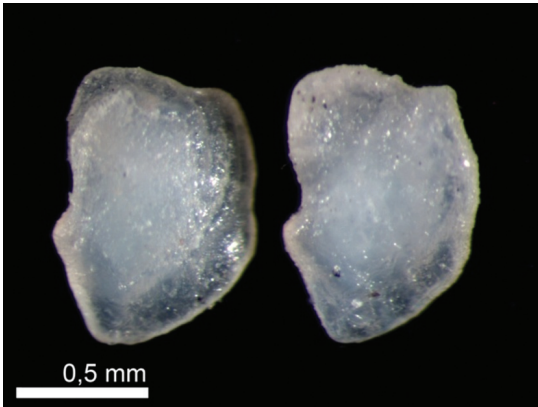


Figure 5. *Sagitta* otoliths of *Hyphessobrycon luetkenii* (Boulenger, 1887) (FL= 5.0 cm; OL= 1.01 mm).

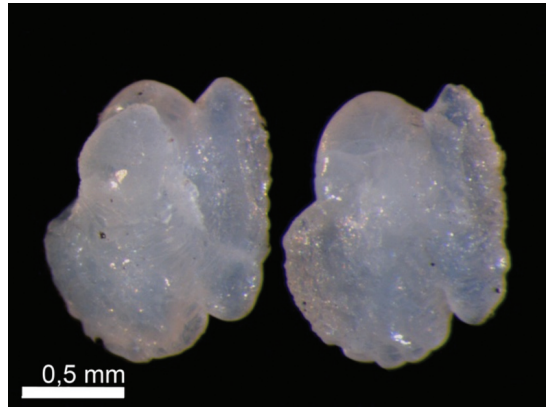


Figure 8. *Sagitta* otoliths of *Piaractus mesopotamicus* (Holmberg, 1887) (FL= 5.5 cm; OL= 1.32 mm).

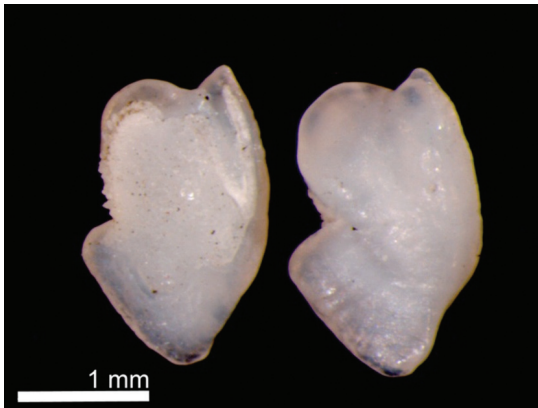


Figure 6. *Sagitta* otoliths of *Oligosarcus robustus* (Menezes, 1969) (FL= 10 cm; OL= 2.36 mm).

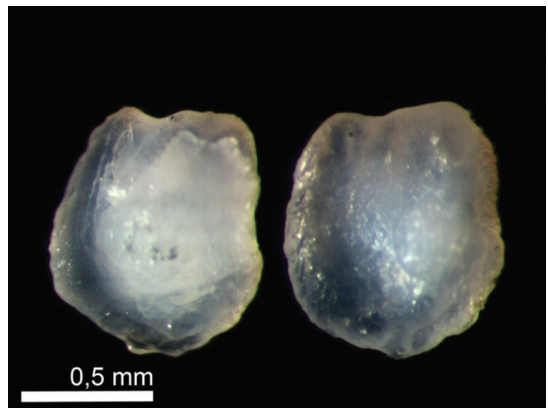


Figure 9. *Sagitta* otoliths of *Pseudocorynopoma doriae* (Perugia, 1891) (FL= 5.7 cm; OL= 0.92 mm).

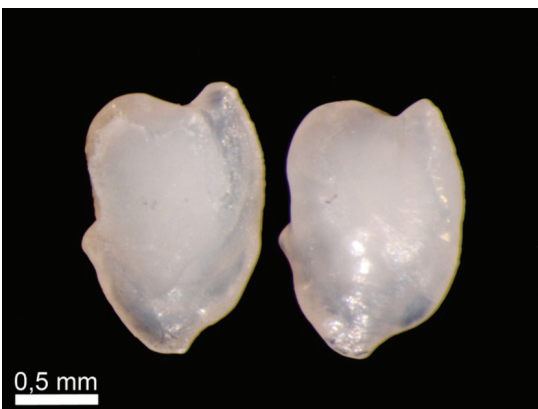


Figure 7. *Sagitta* otoliths of *Oligosarcus jenynsii* (Günther, 1864) (FL= 12.2 cm; OL= 1.66 mm).

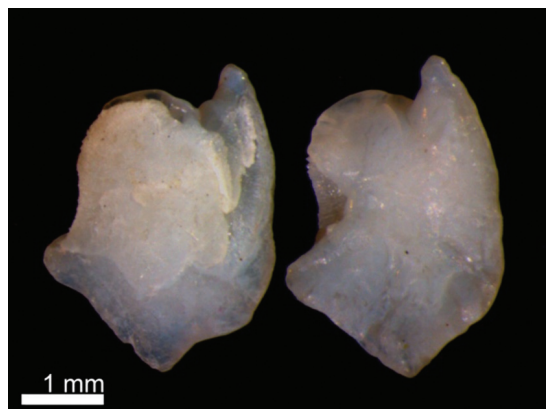


Figure 10. *Sagitta* otoliths of *Salminus brasiliensis* (Cuvier, 1816) (FL= 33.4 cm; OL= 3.73 mm).

Curimatidae (Figure 11)

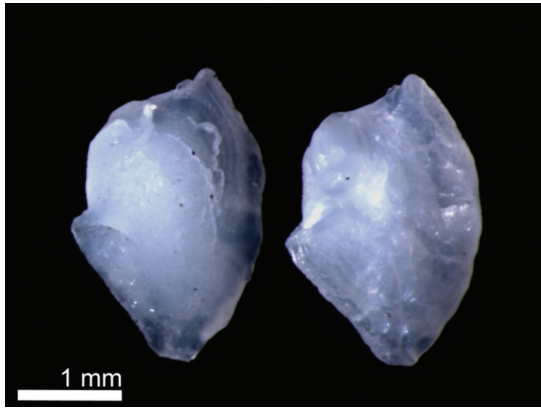


Figure 11. *Sagitta* otoliths of *Cyphocharax voga* (Hensel, 1870) (FL= 13.3 cm; OL= 2.85 mm).

Erythrinidae (Figure 12)

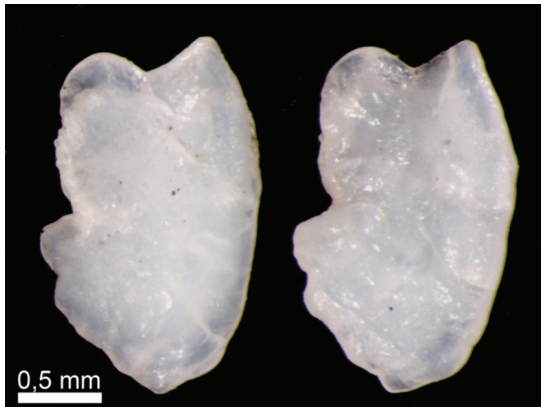


Figure 12. *Sagitta* otoliths of *Hoplias malabaricus* (Bloch, 1794) (FL= 14.3 cm; OL= 2.13 mm).

Prochilodontidae (Figure 13)

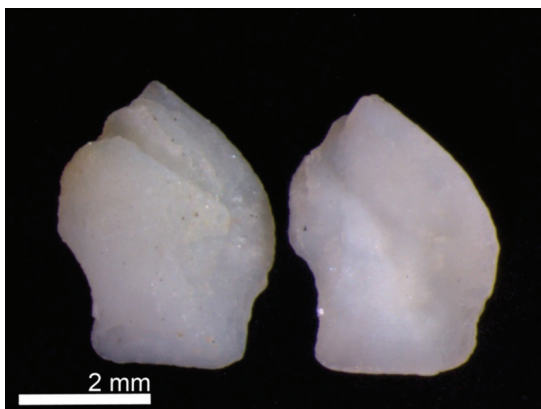


Figure 13. *Sagitta* otoliths of *Prochilodus lineatus* (Valenciennes, 1837) (FL= 29.5 cm; OL= 4.66 mm).

Clupeiformes

Engraulididae (Figure 14)



Figure 14. *Sagitta* otoliths of *Lycenraulis grossidens* (Spix & Agassiz, 1829) (FL= 18 cm; OL= 4.64 mm).

Gymnotiformes

Gymnotidae (Figure 15)

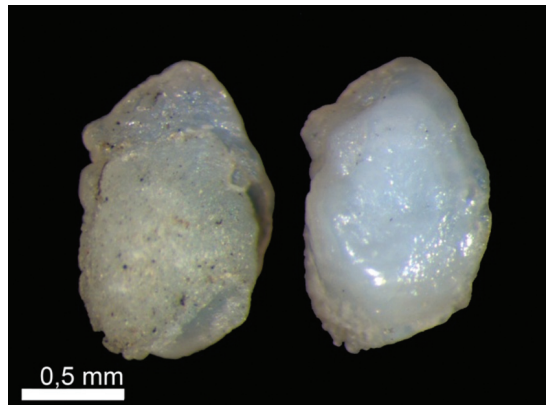


Figure 15. *Sagitta* otoliths of *Gymnotus carapo* (Linnaeus, 1758) (FL= 25 cm; OL= 1.50 mm).

Perciformes

Centrarchidae (Figure 16)

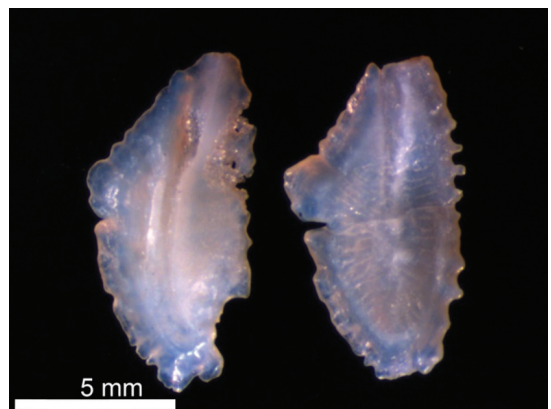


Figure 16. *Sagitta* otoliths of *Micropterus salmoides* (Lacepède, 1802) (FL= 27.1 cm; OL= 9.92 mm).

Cichlidae (Figure 17-24)



Figure 17. Sagitta otoliths of *Australoheros facetus* (Jenyns, 1842) (FL= 9.9 cm; OL= 4.04 mm).



Figure 20. Sagitta otoliths of *Crenicichla punctata* (Hensel, 1870) (FL= 10.9 cm; OL= 4.25 mm).



Figure 18. Sagitta otoliths of *Cichlasoma portalegrense* (Hensel, 1870) (CP= 9 cm; CO= 3.72 mm).



Figure 21. Sagitta otoliths of *Geophagus brasiliensis* (Quoy & Gaimard, 1824) (FL= 7.4 cm; OL= 3.13 mm).



Figure 19. Sagitta otoliths of *Crenicichla lepidota* (Heckel, 1840) (FL= 7.2 cm; OL= 3.61 mm).



Figure 22. Sagitta otoliths of *Gymnogeophagus gymnogenys* (Hensel, 1870) (FL= 12 cm; OL= 4.60 mm).



Figure 23. *Sagitta* otoliths of *Gymnogeophagus labiatus* (Hensel, 1870) (FL= 12.5 cm; OL= 3.90 mm).

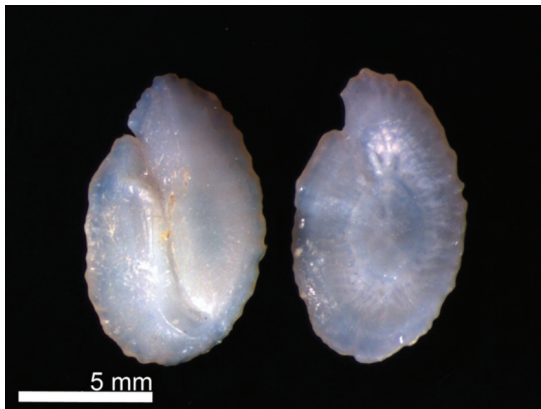


Figure 24. *Sagitta* otoliths of *Oreochromis niloticus* (Linnaeus, 1758) (FL= 24.9 cm; OL= 10 mm).

Sciaenidae (Figure 25)

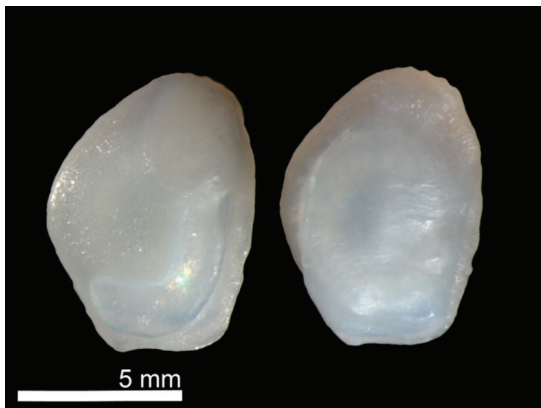


Figure 25. *Sagitta* otoliths of *Pachyurus bonariensis* (Steindachner, 1879) (FL= 14 cm; OL= 8.31 mm).

Siluriformes

Callichthyidae (Figure 26-28)

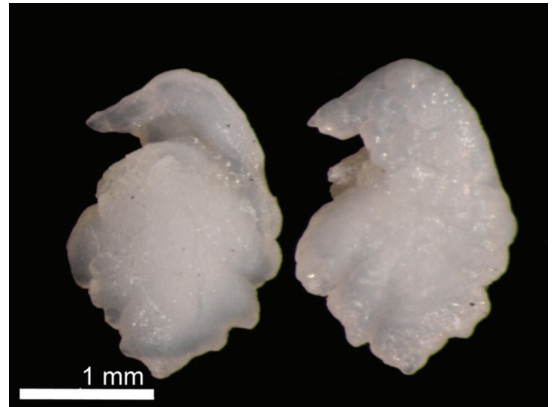


Figure 26. *Sagitta* otoliths of *Callichthys callichthys* (Linnaeus, 1758) (FL= 10.7 cm; OL= 2.33 mm).

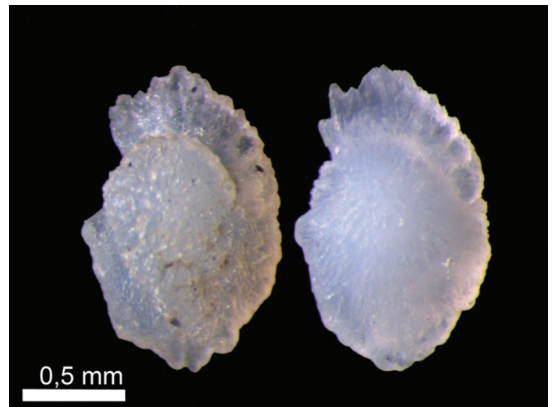


Figure 27. *Sagitta* otoliths of *Corydoras paleatus* (Jenyns, 1842) (FL= 5.6 cm; OL= 1.46 mm).

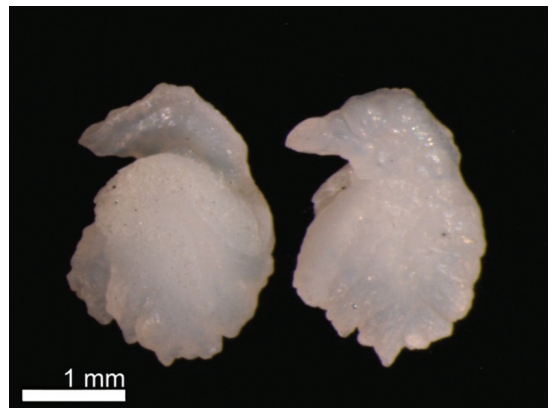


Figure 28. *Sagitta* otoliths of *Hoplosternum littorale* (Hancock, 1828) (FL= 15.4 cm; OL= 2.62 mm).

Heptapteridae (Figure 29 and 30)

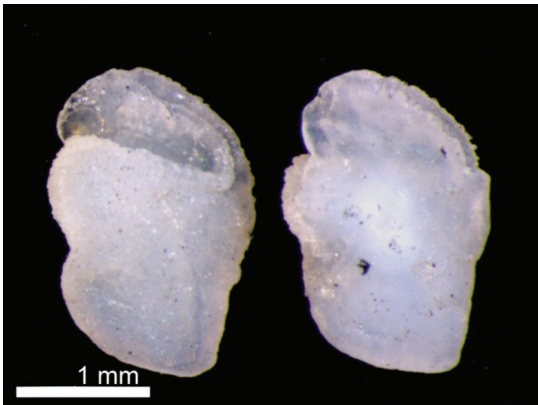


Figure 29. *Sagitta* otoliths of *Pimelodella australis* (Eigenmann, 1917) (FL= 11.6 cm; OL= 2.52 mm).



Figure 30. *Sagitta* otoliths of *Rhamdia quelen* (Quoy & Gaimard, 1824) (FL= 11.2 cm; OL= 4.15 mm).

Loricariidae (Figure 31-33)

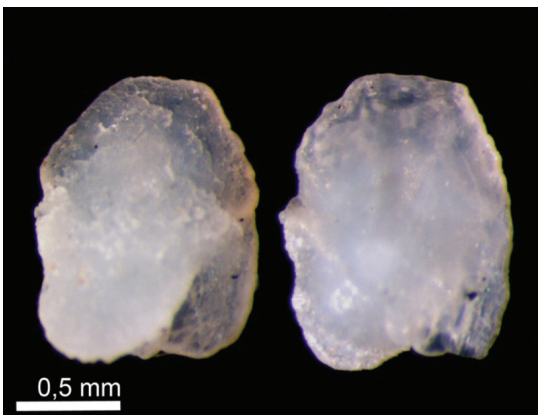


Figure 31. *Sagitta* otoliths of *Hemiancistrus punctulatus* (Cardoso & Malabarba, 1999) (FL= 20.4 cm; OL= 1.39 mm).

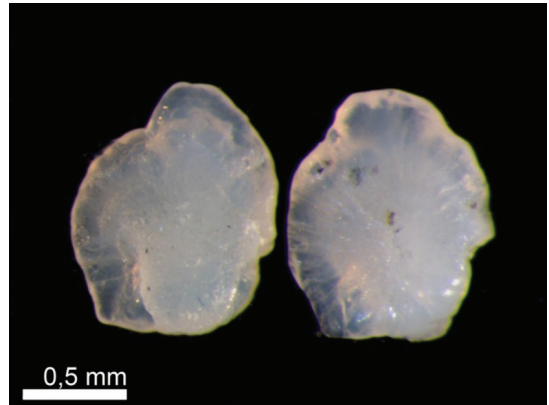


Figure 32. *Sagitta* otoliths of *Hypostomus commersoni* (Valenciennes, 1836) (FL= 11.7 cm; OL= 1.17 mm).

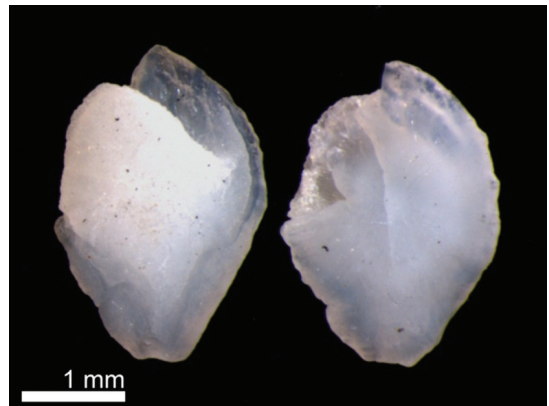


Figure 33. *Sagitta* otoliths of *Loricariichthys anus* (Valenciennes, 1835) (FL= 38.4 cm; OL= 2.97 mm).

Pimelodidae (Figure 34 and 35)

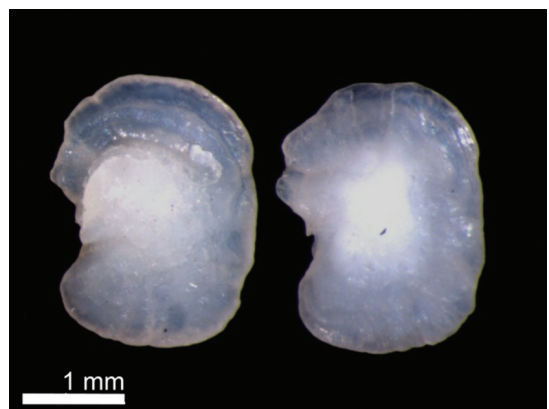


Figure 34. *Sagitta* otoliths of *Parapimelodus nigribarbis* (Boulenger, 1889) (FL= 12.7 cm; OL= 2.71 mm).

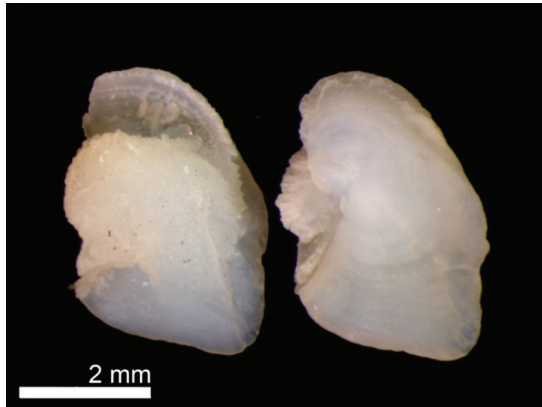


Figure 35. *Sagitta* otoliths of *Pimelodus maculatus* (Lacepède, 1803) (FL= 29.3 cm; OL= 4.37 mm).

Synbranchiformes

Synbranchidae (Figure 36)

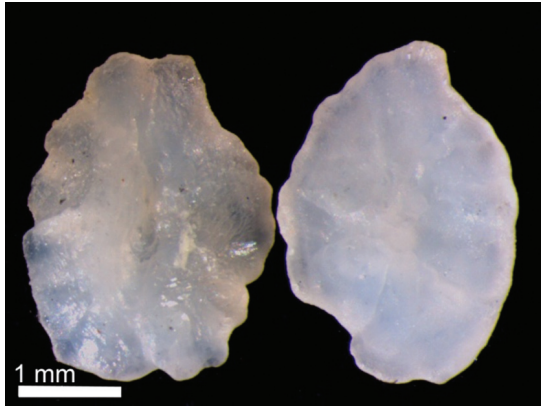


Figure 36. *Sagitta* otoliths of *Synbranchus marmoratus* (Bloch, 1795) (FL= 35 cm; OL= 3.27 mm).

4. Discussion

As reported by Torno (1976) species of the same genus may have very similar otoliths. In this study it was shown that *Gymnogeophagus gymnogenys* and *G. labiatus* and also *Crenicichla lepidota* and *C. punctata* have otoliths that are almost not differentiable.

When considering families, it was possible to identify common features in their morphology. In the families Cichlidae and Characidae, for example, the shape of otolith is very similar in all species. Corrêa and Vianna (1992/93) reported the existence of such common features within families, characteristics like common shape, location of the *sulcus*, form of the *ostium* and otolith tail.

When using otoliths for species identification it should be remembered that the shape and size of the otolith may differ in different life stages of individuals. Most larval stages do not display a specific shape. The final shape is defined only in the juvenile stage (Campana, 2004).

The similarity of otolith shape may impede the exact identification of species in some cases (Tuset et al., 2008). However, with this atlas it may be possible to have a handy visual reference for an easy identification of the diet of ichthyophagous species of the Sinos river and also adjacent basins with similar fish assemblies.

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