Sound absorption structure and chambers in otoliths of Chinese Bahaba (*Bahaba taipingensis*): A "Giant Panda" fish species

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Abstract

As a critically endangered (CR) fish species, Chinese Bahaba is a unique “Giant Panda” fish species in China and has been listed among the national first-class wildlife protection animals and China's top 10 genetic resources of aquatic products since 2021. This fish species is of high commercial value because of its swim bladder that is commonly used in traditional Chinese medicine. Its otoliths are the sensory organs immersed in the endolymph for maintaining its balance and hearing. However, rare information has been reported on the sound absorption structure and chambers of otoliths of such “Giant Panda” fish. The big “C” groove was found in the fish’s front sagittal otolith with the crystal cluster in the back sagittal otolith, the former of which is a 3D layered structure, that is constructed by elongated prismatic crystals. Besides, there are numerous small holes and adhesion material in this 3D layered structure, where many chambers were also found, indicating that some specific sounds may be captured by this structure and these chambers may then amplify such sounds at a certain wavelength. This finding could be of great importance for protecting and conserving this critically endangered species.

Introduction

Chinese Bahaba (*Bahaba taipingensis*) (Fig. 1B), also known as the giant yellow croaker, is one of the largest croakers (Sciaenidae family). It has very limited geographical distribution for it can only be found in south China, from the Pearl River Estuary (PRE), Hong Kong, Macau, and northwards to the Yangtze Estuary. What’s worse lies in the fact that human activities (e.g., overfishing, coastal pollution, etc.) have further threatened their habitats, causing a dramatical decline in its population (Wei and others 2021; Zhang and others 2018). As a “Giant Panda” fish species, Chinese Bahaba has been listed among the national first-class wildlife protection animals and China's top 10 genetic resources of aquatic products in China since 2021. Moreover, as a critically endangered (CR) species that is of highly commercial value in that its swim bladder is commonly used in traditional Chinese medicine, it is confronted with an extremely high risk of extinction in the wild (IUCN 2020; MARAC 2021a; MARAC 2021b).

As a member of the Sciaenidae family, Chinese Bahaba has also been found to generate some species-specific sounds for communicative purposes during reproduction, and feeding, etc. It is more sensitive to sounds compared to other fish families (Wei and others 2021; Zhang and others 2018). However, few reports have been found regarding the sound capture, particularly, the foundation of material structure of the members of the Sciaenidae family including Chinese Bahaba.

Fish otoliths are the sensory organs immersed in the endolymph helpful for maintaining balance and hearing (Armarego Marriott 2021; Popper and Lu 2000; Söllner and others 2003). They were found of metabolically inert carbonate structure, that is, they have been subject to no chemical alterations or reabsorption whenever formed (Söllner and others 2003). Chemically, they are mainly composed of calcium carbonate and precipitated as aragonite under a high molecular weight protein matrix (Carvalho and others 2019). This process is regulated by hormones and influenced by environmental factors (Oxman and others 2007). Numerous studies have been reported on the microchemistry of fish otoliths,

and the relationships between fish species and their environments, as well as the reconstruction of environments (e.g. (Andrus and others 2002; Brennan and others 2015; Chang and Geffen 2013; Wood and others 2022; Yang and others 2011)). However, rare information has been found about the material structure that affects the fish hearing. This paper takes the initiative in reporting the sound absorption structure and the chambers of otoliths of Chinese Bahaba, the “Giant Panda” fish species. It is expected to provide some enlightenments in protecting and conserving such endangered species.

Material And Methods

The PRE is the habitat of Chinese Bahaba aged 0–10. In 2018, specimens of the dead Chinese Bahaba were collected from the PRE (Fig. 1). Chinese Bahaba otoliths were removed, cleaned and kept dry for morphologic observation (Carvalho and others 2019).

The light micrographs were obtained using a Zeiss AXIO ZoomV16 stereo microscope system. The scanning electron microscopy (SEM) images and Raman spectra of otoliths were acquired using a field emission scanning electron microscope (TESCAN MAIA 3GMU) with energy dispersive X-ray spectroscopy (OXFORD ULTIM MAX 170). The otolith was uncoated and imaged in partial vacuum using backscatter or secondary electron detectors at an accelerating voltage of either 10-20keV. Energy dispersive X-ray spectroscopy analyses with Large Area Mapping (LAM) technique was completed using an accelerating voltage of 20 keV for acquisition rate ~ 130000cps/s. The X-ray microcomputed tomography (Micro-CT) images and movie of otoliths were obtained using 3D X-ray microscope (Zeiss Xradia 520 Versa) at an X-ray voltage of 50 kV (power 4W) or 60 kV (power 5W), respectively.

The above experiments of morphologic observation were performed at State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences.

Results And Discussion

The big “C” groove was found in the front sagittal otolith with the crystal cluster firstly found in the back sagittal otolith (Figs. 1C, 2A, 3A, 3B, 3C and the movie of micro-CT reconstruction in Supplementary material). The mineral analysis showed that the sagittal otolith of Chinese Bahaba is a mineral called aragonite made of calcium carbonate (Fig. 2B). The scanning electron microscopy (SEM)images demonstrate that the sagittal otolith is a 3D layered structure that is constructed by elongated prismatic crystals (Figs. 2E-2K, 2M, 2N). Meanwhile, there are numerous small holes (Figs. 2E, 2F, 2H, 2J, 2L, 2M) and adhesion material (Figs. 2G, 2I) in such 3D layered structure, implying some sounds can be captured by this structure.

The X-ray microcomputed tomography (Micro-CT) was adopted to explore the sagittal otoliths of Chinese Bahaba, finding many chambers there (Fig. 3 and the movie of micro-CT Slices in Supplementary material). Previous study of our team showed that Chinese Bahaba is particularly sensitive to certain

sounds (Zhang and others 2018). In this sense, theses chambers are assumed to amplify the sounds at a certain wavelength.

Conclusions

As a critically endangered (CR) fish species, Chinese Bahaba (*Bahaba taipingensis*) is one of the largest croakers (Sciaenidae family) and a unique “Giant Panda” fish species in China, which is very sensitive to sound. Fish otoliths are the sensory organs for maintaining balance and hearing. However, rare information related to otolith material structure has been reported. Data from light microscopy, field emission scanning electron microscope, energy dispersive X-ray spectroscopy, energy dispersive X-ray spectroscopy, X-ray microcomputed tomography (Micro-CT), and Raman spectroscopy that sound absorption structure and chambers in otoliths of Chinese Bahaba were clearly found. The combination of these techniques is substantially effective to resolve the otolith structure.

Declarations

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Figures

Figure 1

The map showing the habitat of Chinese Bahaba aged 0-10 and the dead Chinese Bahaba collected in this habitat (A), and the picture of Chinese Bahaba (B) and the light micrograph of sagittal otoliths used in this study (C).

Figure 2

The scanning electron microscopy (SEM) images and the mineral analysis of the sagittal otoliths of Chinese Bahaba. (A) The back view of microtomographic reconstruction. (B) Raman spectra of the sagittal otoliths of Chinese Bahaba and the aragonite standard materials (R150021 and R060195); Raman spectra of aragonite standard materials (R150021 and R060195) from RRUFF database (https://rruff.info/). (C-N) SEM backscattered images of sagittal otoliths.

Figure 3

The X-ray microcomputed tomography (Micro-CT) images of the sagittal otoliths of Chinese Bahaba.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- MovieofMicroCTSlices.mp4
- MovieofMicroCTreconstruction.mpg