Anatomical details of rare electric fish revealed by an advanced imaging technique

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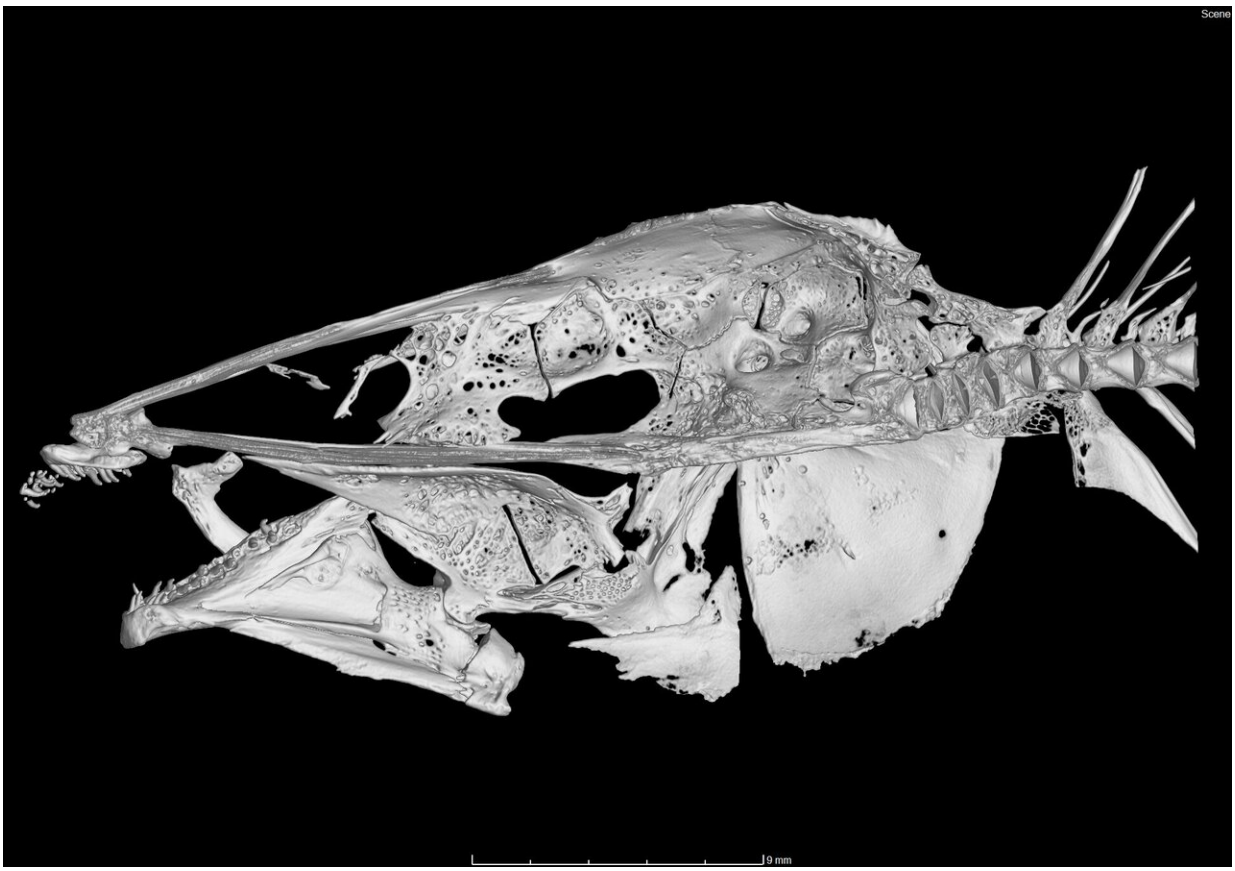

Thanks to the use of high-resolution microcomputed tomography, a cross-border research collaboration was able to study the only three known specimens of Tembeassu marauna, held at the University of São Paulo's Zoology Museum. Credit: Alberto Carvalho e Luiz Peixoto

In an article published in the journal *PLOS ONE*, a group of researchers supported by FAPESP has updated the description of the Ghost knifefish, Tembeassu marauna, a neotropical electric fish species found only once in the wild.

The study, conducted in Brazil, was based on an analysis of external anatomy and internal details that could be seen thanks to an advanced, high-resolution computed tomography (CT) technique that revealed characteristics of the fish's bones without requiring dissection.

"The only three known specimens of T. marauna are preserved in the University of São Paulo's Zoology Museum [MZ-USP], and because they're the only ones, they can't be dissected or bathed in iodine to make their internal organs and other soft tissues visible in a CT scan. These problems hinder studies of this species," Luiz Antonio Wanderley Peixoto, first author of the article, said.

The study was conducted during Peixoto's postdoctoral fellowship and supervised by Professor Aléssio Datovo da Silva, a coauthor of the article. The scientists studied the osteology (bone structure) of the 17-centimeter specimens by X-ray microcomputed tomography (microCT scanning), comparing their internal details with those of similar fish to establish a better classification of the species. The previous classification was based only on observation of its external anatomy and conventional X-rays.

They conducted the research in collaboration with colleagues at the Federal University of Rio de Janeiro State (UNIRIO) in Brazil and the National Museum of Natural History (NMNH), administered by the Smithsonian Institution in the United States.

The group's objective is to advance knowledge of electric fish. There are currently more than 250 known species of fish that can emit and detect

low-voltage electric discharges to guide navigation, find mates or stun prey. The same research group recently described two new species of electric eel, the only electric fish capable of producing a powerful enough shock to capture their prey. One of these new species can produce the highest voltage of any known living being.

Single occurrence

The three known specimens of T. marauna were collected from the Paraná River in Brazil in 1965 during construction of the Ilha Solteira dam and hydroelectric power plant on the border between the states of São Paulo and Mato Grosso do Sul. They appeared to inhabit the main channel, the deepest part of the river, and were caught only because they were in a cofferdam area that had been drained to enable construction work below the waterline.

The specimens were deposited in the MZ-USP's collection, but the species was not formally described until 1998. The description was based on external anatomy and carried out by Mauro Triques, who earned a Ph.D. at MZ-USP with a scholarship from FAPESP. Triques is now a professor at the Federal University of Minas Gerais (UFMG).

At the time, Triques noted the existence of "an enlarged, fleshy, lateral lobe on the chin," concluding that it was a distinctive feature that was absent or less developed in related species. He considered this trait sufficient to differentiate T. marauna from other species in the same order.

In 2005, Ricardo Campos-da-Paz, currently a professor and researcher at UNIRIO, described a set of some 15 extra teeth on the upper lip of all three specimens with no connection to the premaxillary bones, as occurs in other species.

"The presence of these teeth may have something to do with a specific diet, possibly a type of prey only the species in question is able to capture. We have no way of knowing because we have no information on the stomach content of these specimens," Peixoto said. "Another hypothesis is that the teeth reflect some specific behavior, such as competing for resources with adversaries. The function of the hypertrophied lobe on the chin or lower lip could be to receive electric signals and communicate with potential mates. We can't be certain without an analysis of the inside of these structures."

Expeditions to the dam and environs have been conducted over the years to try to collect more specimens and answer these and other questions, but without success. Because of the single occurrence in the Paraná River and the lack of new specimens, the species is considered "critically endangered" by the Brazilian authorities and classed as "possibly extinct" in the Fish & Aquatic Invertebrates section of the Official National List of Endangered Species, where its common name is "ituí-maraúna," which is not found in any scientific record.

Genetic tests are also a problem because the specimens were originally preserved in formalin, which destroys DNA and prevents its extraction using the currently available techniques. However, researchers are attempting to use antiquated DNA extraction techniques, which are expensive and do not always work but, in some cases, may recover part of the genetic code.

MicroCT scanning proved the most appropriate technique to study the specimens in light of these difficulties. Analysis of the ultra-high-resolution images of the skeletons produced by the microCT scan enabled the researchers to class T. marauna more precisely in the family Apteronotidae (Ghost knifefish), which, in turn, is part of the electric fish order Gymnotiformes.

Phylogenetic analysis confirmed that this species is the only one in the genus Tembeassu. It also showed that this animal may be closest in evolutionary terms to the genera Megadontognathus and Apteronotus. Species in the latter genus, such as A. albifrons and A. jurubidae, are popular knifefish among home aquarium lovers.

"This study exemplifies how cutting-edge technology can help analyze biological material deposited in zoological collections. The microCT technique enables researchers to perform noninvasive examination of rare specimens whose internal anatomy couldn't otherwise be studied in detail. In addition, the high-resolution images and 3-D videos it produces can serve as classroom material and can be used for scientific dissemination," said co-author Carlos David de Santana, a research associate at NMNH.

More information: Luiz A. W. Peixoto et al, Anatomical, taxonomic, and phylogenetic reappraisal of a poorly known ghost knifefish, Tembeassu marauna (Ostariophysi: Gymnotiformes), using X-ray microcomputed tomography, *PLOS ONE* (2019). DOI: 10.1371/journal.pone.0225342

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