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Short Communication

First report of *Oreochromis niloticus* in the Sonora River, Mexico

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ABSTRACT. Commercial farming of tilapia species has been spread to many countries worldwide to meet the need for animal protein at an affordable price, which has led tilapias to invade natural areas. Consequently, tilapias have established wild populations, causing a great negative impact on native biodiversity. The Sonora River, located in northwest Mexico, has an approximate length of 400 km, and at least four native fish species inhabit it. Nevertheless, the Sonora River has been severely reduced and contaminated by open-pit mining. According to existing knowledge, the presence of tilapias is not reported in the Sonora River; hence, the present study is the first report of the presence of the Nile tilapia *Oreochromis niloticus* in a site near the town of Baviácora, Sonora, Mexico. The presence of this invasive species may represent a severe threat to the biotic component of this ecosystem, which is already affected by mining pollution.

Keywords: *Oreochromis niloticus*; freshwater species; exotic fish; invasive fish; cytochrome oxidase I; molecular identification

The tilapias are a group of tropical freshwater fish of the family Cichlidae (genera *Oreochromis*, *Tilapia*, and *Sarotherodon*), native to Africa and intentionally introduced to many countries around the world since the 1930s with a variety of purposes, such as biological control of macrophytes and insects, aquarium hobby, and for human consumption (Costa-Pierce 2003, Canonico et al. 2005). Due to their easy adaptation to different environmental conditions, they are an important component of aquaculture production in many countries. The Nile tilapia (*Oreochromis niloticus*) is the most farmed tilapia species in the world (FAO 2022).

Brazil, Colombia, Honduras, and Mexico are considered the most important Latin American producers of tilapia, whose production is consumed locally, and a significant part exported to other regions, obtaining a good profit from it (FAO 2023). However, they are considered a dangerous invasive species due to the tilapias' high reproduction rates and ability to adapt to local conditions and escape from farming facilities. Additionally, some reports indicate that tilapias have established wild populations in countries where they are cultured, causing competition for habitat and food resources and predation of local species, which have been displaced or, in some severe cases, replaced (Morgan et al. 2004, Canonico et al. 2005, Russell et al. 2012, Lawson et al. 2015). In Mexico, serious consequences have been reported as species displacement due to the establishment of wild tilapia populations in the southeast of the country, specifically in the states of Yucatán, Quintana Roo, Campeche, and Tabasco (Strecker 2006, Amador-del Ángel & Wakida-Kusunoki 2014), as well as in the Baja California peninsula (Ruiz-Campos et al. 2014). According to existing knowledge, tilapias have not been reported in the Sonora River; hence, the present study is the first report of *O. niloticus* in the Sonora River, located in northwest Mexico in the state of Sonora.

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The Sonora River rises in a place known as Ojo de Agua de Arvayo (30°57'38"N, 110°11'29"W), located 10 km to the east of the city of Cananea, Sonora, Mexico, and flows a trajectory of 400 km to end in the Abelardo L. Rodríguez dam (the main freshwater reservoir of the city of Hermosillo, Sonora). Due to the excessive water extraction for mining purposes, the Sonora River has become a low-flow river. Additionally, in drought conditions, the river turns intermittent, flowing into the El Molinito dam, located 25 km upstream of the Abelardo L. Rodríguez dam. In extreme drought conditions, the river hardly reaches this area.

Water scarcity in Sonora can be traced back to the 1990s when the state was declared a severe drought mainly caused by the lack of rainfall (Hernández-Vásquez et al. 2022a). Additionally, studies based on historical rainfall data indicate that Sonora's most intense drought periods were registered in 1997, 1999, 2000, and from 2011 to 2013 (Hernández-Vásquez et al. 2022b). In addition to this severe condition, on August 6, 2014, the Sonora River was severely contaminated by mining activity, receiving approximately 40,000 m^3 of acidulated copper sulfate, becoming the largest environmental disaster in northwest Mexico that affected the entire river basin (Díaz-Caravantes et al. 2016, 2018), including flora, fauna, and groundwater (SEMARNAT 2023).

Due to the above, it is a high priority to perform scientific studies focusing on the condition of flora and fauna that inhabit this ecosystem since there is evidence that indicates a prevalence of high impact levels after nine years of the spill. In this way, a prospecting visit was made to the Sonora River to search for suitable sampling sites and identify the presence of fish for future research on the effect of pollution in the area. On June 26, 2022, upon arriving at a site on the Sonora River (29°41'30.79"N, 110°09'48.88"W) near the town of Baviácora (Fig. 1), the local guide sighted the presence of a school of fish on the riverbank, where there was no more than 40 cm depth. Six fish were carefully captured using an aquarium hand net (8×6", 4.5" depth, 1/16" mesh), and after careful inspection by eye, it was determined that they belonged to the poecilid family. Subsequently, the guide sighted a second school of small fish of no more than 10 cm in total length, but due to the agility of the fish, only four organisms from that school could be captured. After a closer inspection, the fish seemed to be tilapia.

Nevertheless, because tilapias have not been reported to inhabit the area, the fish were placed individually in resealable plastic bags and inside a cooler with ice for further analysis. The organisms were transported to the Molecular Ecology Laboratory of the University of Sonora in the City of Hermosillo, Mexico. They were carefully examined following the identification criteria established by Trewavas (1983). The four fish were successfully identified as *O. niloticus* (Fig. 2). In the same laboratory, we carried out the organisms' molecular analysis.

Twenty milligrams of muscle tissue were obtained from two organisms. The tissues were placed in sterile 1.5 mL Eppendorf tubes with >95% ethanol and kept at -20°C until processing. For DNA extraction, the QIAamp DNA Mini Kit was used following the manufacturer's instructions (QIAGEN). Concentration and purity were estimated in a Nanodrop 1000 spectrophotometer (Thermo Fisher Scientific). A section of 707 base pairs of the mitochondrial *COI* gene was amplified with the oligos FishF1: 5'-TCAAC CAACCACAAAGACATTGGCAC-3' and FishR1: 5'-TAGACTTCTGGGTGGCCAAAGAATCA-3' reported by Ward et al. (2005). The reaction mixture was prepared in a final volume of 20 µL that included 10 µL of Taq Polymerase Master Mix solution (Thermo Fisher Scientific), 50 ng of DNA, 10 pmol of each oligonucleotide, and PCR grade water to supplement the final volume. PCR conditions were as suggested by Ward et al. (2005): initial denaturation at 95°C for 2 min, 35 cycles of 94°C for 30 s, 54°C for 30 s and 72°C for 60 s, and a final extension at 72°C for 10 min. The PCR product was verified on 1% agarose electrophoresis stained with GelRed (Biotium).

The amplicons were purified using the QIAquick PCR Purification kit following the manufacturer's instructions (QIAGEN) and sent to the sequencing service of the Institute of Biotechnology of the Universidad Nacional Autónoma de México (UNAM). Sequences were edited in ChromasPro v. 2.1.10.1, and subsequently, a BLAST analysis was performed in GenBank to search for identities and select sequences to perform a maximum likelihood phylogenetic analysis based on the 2-parameter Kimura method with 1000 replicates and the nearest neighbor exchange (NNI) heuristic method using the MEGA11 software.

The organisms analyzed presented the same sequence and were registered in GenBank with the accession number OR728058. BLAST analysis showed 92-100% identities with *Oreochromis* species records, with 87% of those records indicating >99% identity. Forty-nine percent of these records in GenBank are not defined at the species level, only at the genus level. Phylogenetic analysis with *Oreochromis* sequences recorded at the species level in GenBank and with

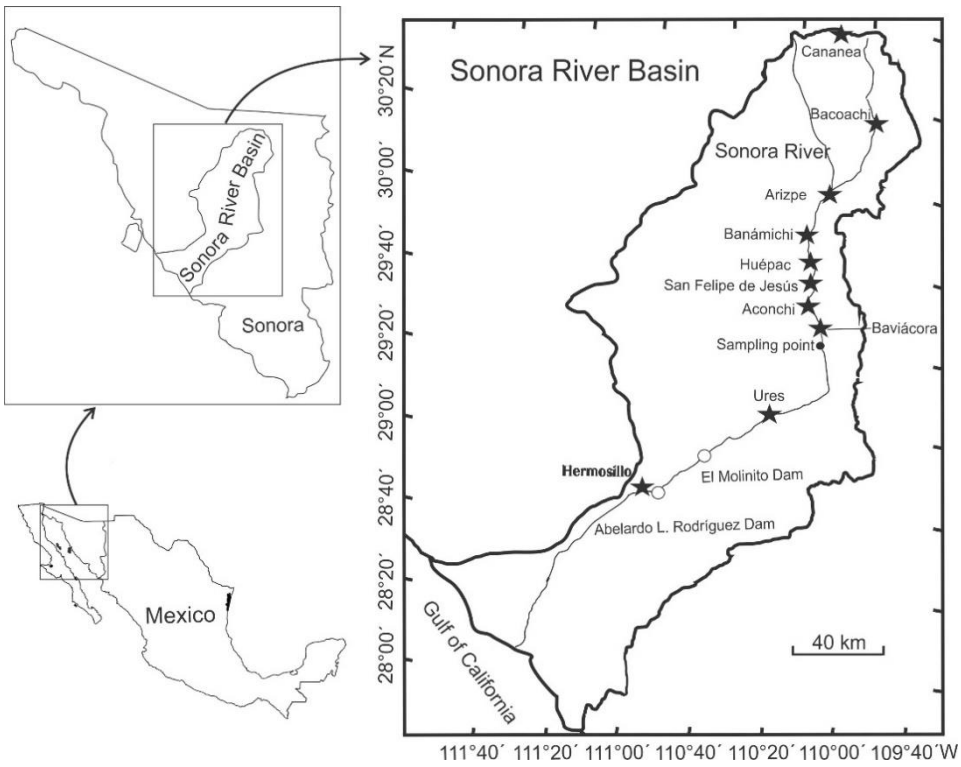

Figure 1. Sonora River basin showing the sampling site (black circle), the dams (white circles), and towns (stars).

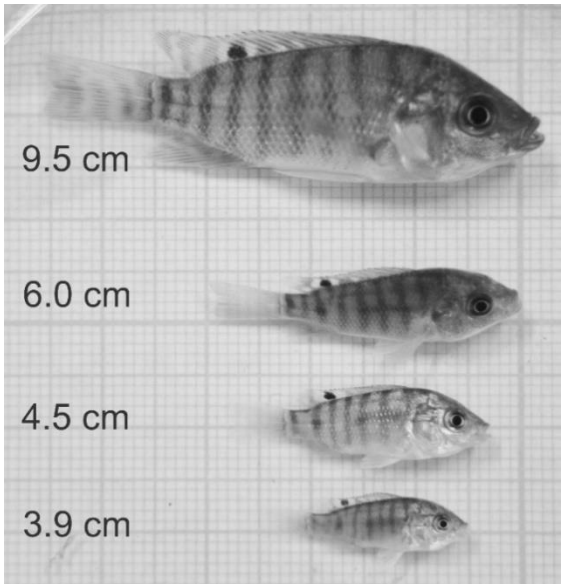

Figure 2. *Oreochromis niloticus* juveniles from the Sonora River near Baviácora, Sonora, Mexico.

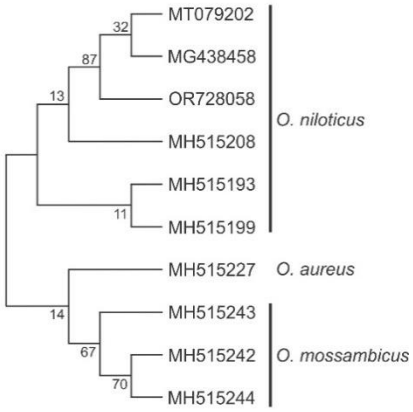

Figure 3. Maximum likelihood phylogenetic tree using the Kimura 2-parameter model for nucleotide substitutions with 1000 bootstrap replications, and using the option of the heuristic method of the Nearest-Neighbor-Interchange model for tree inference from the mitochondrial *COI* gene for sequence OR728058 obtained in this study and sequences for tilapia species reported in GenBank. Numbers on the arms: bootstrap values.

identities >99% (Table 1) showed that the sequence obtained from organisms collected from the Sonora River grouped with *O. niloticus* sequences (Fig. 3).

The invasion of tilapia species has been reported in several regions of Mexico, causing a great impact on natural ecosystems and local biodiversity. Ruiz-Campos et al. (2014) stated that there are records in northwest Mexico of an invasion of *O. aureus* and *Tilapia* cf. *zillii* in the states of Baja California, Sonora

Table 1. BLAST analysis shows high identity and coverage among tilapia species (*Oreochromis niloticus* and *O. mossambicus*) registered in GenBank with the sequence OR728058 from the Sonora River.

GenBank accesion number	Species	Cover query (%)	Identity (%)	e-value
MT079202	*O. niloticus*	99	100	0
MH515208	*O. niloticus*	99	99.29	0
MH515199	*O. niloticus*	99	99.29	0
MH515193	*O. niloticus*	99	99.29	0
MH515227	*O. aureus*	99	99.15	0
MG438458	*O. mossambicus*	100	99.15	0
MH515243	*O. mossambicus*	99	99.15	0
MH515242	*O. mossambicus*	99	99.01	0
MH515244	*O. mossambicus*	99	98.86	0

(Colorado River) and Sinaloa, including hybrids of *O. aureus* and *O. mossambicus*. Additionally, there is evidence that supports the invasion and establishment of wild tilapia populations in other regions of Mexico: *O. aureus*, *O. mossambicus*, *O. niloticus*, *Tilapia rendalli*, and *T. zilli* in Oaxaca, Michoacán, Guerrero and Morelos (Espinosa-Lemus et al. 2009, Contreras-MacBeath et al. 2014); *O. aureus* and *O. mossambicus* in Chihuahua, Coahuila, Nuevo León and Tamaulipas (Lozano-Vilano & García-Ramírez 2014); *O. niloticus* has been reported in Tabasco, Campeche, Yucatán and Quintana Roo; *O. aureus* in Tabasco; *O. mossambicus* in Tabasco, Quintana Roo and Campeche; *T. rendalli* in Tabasco (Amador-del Ángel & Wakida Kusunoki 2014).

The presence of *O. niloticus* in the Sonora River is difficult to explain. The basin is a severely impacted region dedicated primarily to agricultural and livestock activities, with no fish farming facilities in the surrounding area. Someone may have had a transiently small tilapia farm for family consumption and released tilapia into the river. Still, it is impossible to establish who it was, where they did it, and when. In Sonora, there are four large dams where *O. niloticus* is cultured. Still, they are situated in different basins: the Mocúzari dam is in the Mayo River basin (Balderrama-Carmona et al. 2019), while the El Novillo, El Oviachic, and La Angostura dams are situated in the Yaqui River basin (Martínez-Durazo et al. 2020, Montoya-Camacho et al. 2020). It is worth mentioning that the Sonora River discharges its waters into the El Molinito dam, where *O. niloticus* is exploited commercially by artisanal fishery. However, it is important to consider that the El Molinito dam is located 85 km downstream from where the fish were sampled, and considering the low flow of the river, it is improbable for fish to swim an upstream invasion trajectory. Additionally, due to the small size of the specimens, tilapia fingerlings found in the Sonora River may be the product of a reproduction event close to the sampling date.

Due to the background on the effects of the invasion of exotic species such as tilapia, the presence of *O. niloticus* in the Sonora River may represent a risk for the basin's ecosystem and biodiversity (Mendoza-Alfaro & Koleff-Osorio 2014). Native fish species of the Sonora River, such as *Catostomus wigginsi*, *Gila eremica*, *Campostoma ornatum*, and *Poeciliopsis occidentalis*, may be significantly affected by the threat of predation, competition for food and space. Some native species are considered threatened (Varela-Romero & Hendrickson 2010, Chávez-Toledo et al. 2013). Therefore, we recommend that future research in the Sonora River should focus on evaluating the population density of *O. niloticus*, its latitudinal distribution along the river, the negative implications for native biodiversity, and the feasibility of a strategy for eradicating this species.

Credit author contribution

R. Castro-Longoria: conceptualization, funding acquisition, project administration, methodology, formal analysis, writing-original draft; Á. Martínez-Durazo, C. Minjarez-Osorio & E. de la Re-Vega: methodology, formal analysis, review, and editing; J.M. Grijalva-Chon: methodology, formal analysis, data curation, validation, writing-original draft. All authors have read and accepted the published version of the manuscript.

Conflict of interest

The authors declare no potential conflict of interest in this manuscript.

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