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The Mozambique Tilapia (*Oreochromis mossambicus*), in hypersaline waters of Venezuela, Southeastern Caribbean Sea

La Tilapia de Mozambique (*Oreochromis mossambicus*) en aguas hipersalinas de Venezuela, Sureste del Mar Caribe

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ABSTRACT

The Mozambique Tilapia *Oreochromis mossambicus* (Peters 1852), is a euryhaline species, native to Southeast Africa. Its introduction in the Southeast Coastal Caribbean region (Venezuela) dates back to 1964. Since then, due to its adaptive plasticity, it has invaded different freshwater, estuarine and marine ecosystems, such as the Manzanares and Barbacoas rivers, the coastal lagoons of Los Patos, Punta Delgada, Campoma and Los Mártires (Isla de Margarita), as well as coastal waters of the Golfo de Cariaco. The present study adds the hypersaline lagoon system of Chacopata and Bocaripo to these biomes. The salinity recorded in that ecosystem varies from 32 to 71 PSU. This lagoon system is located on the North coast of the Península de Araya, constituting an advance of the invasion of this species in the Eastern coast of Venezuela. The first record of this species was on November 2017 and second in March 2023, with the capture and analysis of 17 and 19 specimens, and highlights the establishment of *O. mossambicus* in hypersaline waters, typical of a negative estuary. We describe the basic morphological identification characteristics, as well as the possible pathways of the introduction. Likewise, based on the information available on its presence and establishment in at least 94 countries, and the different kinds of negative impacts it has caused on biodiversity in the invaded ecosystems, management measures are proposed. Among these measures, both the monitoring of the evolution of the species in the Chacopata and Bocaripo lagoon system and the possible changes to the native known aquatic biota stand out.

Keywords: biological invasions, Cichlidae, coastal marine lagoons, hyperhaline waters, negative estuaries, non-native species.

RESUMEN

La Tilapia de Mozambique *Oreochromis mossambicus* (Peters 1852), es una especie eurihalina, originaria del Sureste de África. Su introducción en la región Sureste costera del Mar Caribe (Venezuela) se remonta a 1964. Desde entonces, debido a su plasticidad adaptativa, ha invadido diferentes ecosistemas de agua dulce, estuarinos y marinos, como los ríos Manzanares y Barbacoas, las lagunas costeras de Los Patos, Punta Delgada, Campoma y Los Mártires (Isla de Margarita), así como aguas costeras del Golfo de Cariaco. El presente estudio agrega a estos biomas el sistema de lagunas hipersalinas de Chacopata y Bocaripo. La salinidad registrada en ese ecosistema varía de 32 a 71 USP. Este sistema lagunar que se ubica en la costa Norte de la Península de Araya, constituye un avance de la invasión de esta especie, en la costa oriental de Venezuela. El primer registro de esta especie fue en noviembre de 2017 y el segundo en marzo de 2023, con la captura de 17 y 19 ejemplares, lo que destaca el establecimiento de *O. mossambicus* en aguas hipersalinas, propias de un estuario negativo. Describimos las características morfológicas básicas de identificación, así como las posibles vías de introducción. Así mismo, a partir de la información disponible sobre su presencia y establecimiento en al menos 94 países, y los diferentes tipos de impactos negativos que ha causado sobre la biodiversidad de los ecosistemas invadidos, se proponen medidas de manejo. Entre estas medidas, destacan tanto el seguimiento de la evolución de las especies en el sistema lagunar de Chacopata y Bocaripo, así como los posibles cambios en la biota acuática nativa conocida.

Palabras clave: aguas hiperhalinas, Cichlidae, especies exóticas, estuarios negativos, invasiones biológicas, lagunas marino costeras.

INTRODUCTION

Venezuela, with its 2,696 km of coastline in the Southeast Caribbean Sea and 832 km in the Atlantic Ocean as well as its more than 300 islands, islets, and keys (436 km), has a variety of marine ecosystems, such as sandy beaches, coral reefs, rocky coastlines, seagrass beds, deep sea bottoms, and estuaries such as river mouths and coastal lagoons (Conde & Carmona 2003, Miloslavich *et al*. 2005, Miloslavich & Klein 2008). These lagoons, generally predominantly vegetated by the mangrove forest due to their tropical location, may be associated with fluvial systems or not be part of them, so their ecological conditions are markedly different, forming estuaries of positive or negative (hypersaline) type in each case (Cervigón & Gómez 1986). These coastal marine ecosystems are numerous in the country, with at least 35 continental and 24 insular, most of the latter with hypersaline or hyperhaline ecological conditions in negative estuaries (Cervigón & Gómez 1986, Lentino & Brunni 1994, Ramírez & Roa 1994, Ramírez-Villarroel 1996, Conde & Carmona 2003, Medina & Barbosa 2006, Miloslavich *et al*. 2005, Miloslavich & Klein 2008), which have been relatively well studied since the mid-20th century. Regarding the fish fauna, at least 25 important studies have been carried out in at least 23 of these lagoon systems (Weibezahn 1949, Carvajal 1965, Mago 1965, Fernández-Yépez 1970, Carvajal 1972, Gómez 1981, Heredia 1983, Oliveros & Martínez 1984, Acosta 1985, Cervigón & Gómez 1986, Meaño 1986, Jory 1988, Rodenas & López-Rojas 1993, Ramírez-Villarroel 1993, Valecillos 1993, Ramírez-Villarroel 1994a,b, López-Rojas *et al*. 1996, Marín 2000, Andrés De Grado & Bashirullah 2001, González-Bencomo & Borjas 2003, Andrade de Pasquier *et al*. 2005, Barreto *et al*. 2009, Bonilla *et al*. 2010, Pérez *et al*. 2012).

However, environmental problems and threats to the conservation of biodiversity and the marine lagoon ecosystems of Venezuela are numerous and have increased in recent decades. The following stand out among a long list of these: the construction of dams and roads for the establishment and operation of solar salt works; aquaculture farms and communication routes; dredging of channels for navigation; closure of their mouths and communication with the sea; sedimentation due to alteration of the coastline (construction of breakwaters); landfills for urban or industrial expansion; contamination (organic and inorganic) of its waters; oil extraction and transportation; deforestation of mangroves; hydrological and sedimentary changes due to the channeling of rivers into its interior; and the construction of dams in their basins and climate change (Lentino & Brunni 1994, Ramírez & Roa 1994, Medina & Barbosa 2006, Miloslavich *et al*. 2005, Miloslavich & Klein 2008). The introduction of species and their consequent biological invasions, is added to all these environmental problems and threats (Vitule & Prodocimo 2012).

In Venezuela, as in various parts of the world, the introduction of exotic and transferred (translocated) species has been pointed out as a serious problem for the conservation of its biodiversity, also causing degradation of ecosystems and indirect (*e.g.*: economic activities) or direct effects (*e.g.*: transmission of diseases) to humans (Ojasti *et al.* 2001, Lasso-Alcalá 2003, Cassemiro *et al.* 2018, Pyšek *et al.* 2020, Doria *et al.* 2021, Ruiz-Allais *et al.* 2021). In the long term, the worst case scenario that can be expected with introduced species is the invasion and homogenization of the biotas (Baiser *et al*. 2012, Vitule & Pozenato 2012, Daga *et al*. 2020). As far as fish and marine ecosystems are concerned, to date, some six species of fish have been indicated as introduced to the coasts of Venezuela, four estuarine, two marine and finally, at least one of freshwater origin with strong euryhaline habits (Carvajal 1965, Springer & Gomon 1975, Aguilera & Carvajal 1976, Chung 1990, Nirchio & Pérez 2002, Pezold & Cage 2002, Lasso *et al*. 2004, Lasso-Alcalá *et al*. 2005a,b, 2008, Lasso-Alcalá & Posada 2010, Lasso-Alcalá *et al*. 2011, 2019; Cabezas *et al*. 2020, 2022). Among these species, the Mozambique Tilapia *Oreochromis mossambicus* (Peters 1852) stands out for its adaptation and capacity to colonize coastal marine ecosystems, until now only formally flagged as invasive in other coastal lagoons systems of Northeastern Venezuela, such as Laguna de Los Patos, Laguna de Punta Delgada and the Laguna de Campoma, as well as at the mouths of the Manzanares and Barbacoas rivers, the coastal waters of the Golfo de Cariaco and Laguna de Los Mártires, Isla de Margarita (Aguilera & Carvajal 1976, Chung 1990, Chung & Méndez 1993, Solorzano *et al*. 2001, Nirchio & Pérez 2002, Marín *et al*. 2003, Gaspar 2008, Bonilla *et al*. 2010, Rodríguez *et al.* 2021; Fig. 1).

The main objective of this work is to record the introduction of *Oreochromis mossambicus* in the hypersaline lagoon system of Chacopata and Bocaripo, on the Northeastern coast of Venezuela, highlighting its presence in high salinities of this negative estuarine ecosystem. In addition, the possible route of introduction, its implications, biological and ecological consequences on the native fauna and ecosystem are discussed, as well as some recommendations for its study and management are given.

MATERIAL AND METHODS

Study area

The Chacopata and Bocaripo lagoon system is located on the Northeast coast of the Península de Araya, Sucre State, Venezuela (10°40'14" N- 63°48'07" W), Southeast

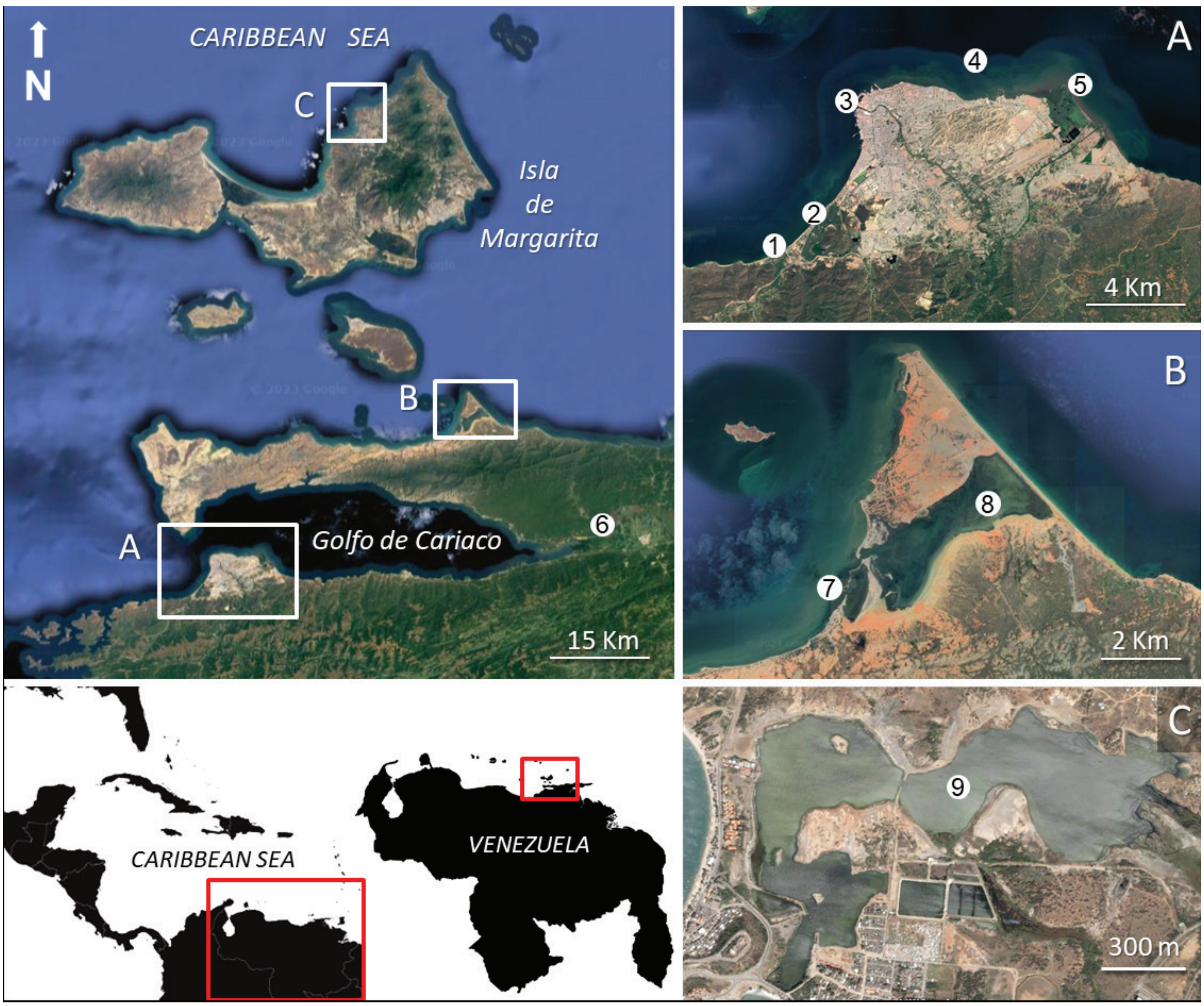

Figure 1. Map of the Southeastern Caribbean Sea (Northeast of Venezuela), showing: A. Coasts of Cumaná and Golfo de Cariaco; B. Chacopata and Bocaripo lagoon system; C. Laguna de Los Mártires, Isla de Margarita. Localities with established populations of *Oreochromis mossambicus*: 1. Río Barbacoas mouth, 2. Laguna de Los Patos, 3. Río Manzanares mouth, 4. Golfo de Cariaco coast, 5. Laguna de Punta Delgada, 6. Laguna de Campoma, 7. Laguna de Bocaripo, 8. Laguna de Chacopata, 9. Laguna de Los Mártires. Source: Modified from Google Earth 2023 base map. SIO, NOAA, NGA, GEBCO data. Image Lansat / Copernicus.

of the Caribbean Sea. It is made up of two coastal or marine lagoons (Fig. 1B), the Laguna de Chacopata with 770 ha and the Laguna de Bocaripo with 77 ha. These two lagoons are separated only by a narrow bar of irregularly shaped sand (Bello *et al*. 2016). Both lagoons, with a depth between 0.5-2 m (Chacopata) and 0.4 to 1 m (Bocaripo), maintain direct communication with the adjacent Caribbean Sea through two openings (mouths), through which seawater enters, a product of the diurnal tide rate (change every 12 hours). Its range is approximately 50 cm, which increases during the spring tide season, in the September to November quarter (Pérez *et al*. 2006a). Due to the high water levels of this last period, the two lagoons enter into direct communication.

Physiographically, this lagoon area is part of the continental coastal region of Venezuela, in both cases bordered by a mixed mangrove forest, dominated in order of surface occupied by *Rhizophora mangle, Avicennia germinans, Laguncularia racemosa* and *Conocarpus erectus* (Cumana *et al*. 2000), as well as seagrass meadows dominated by *Thalassia testudinum* and *Syrigodium filiforme* and abundant macroalgae (*Cladophora* sp. and *Chaetomorpha* sp.) (Jiménez-Ramos *et al*. 2019).

The climate of the region is characterized by strong aridity, caused by the joint action of a very marked dry season (December-May), when the oceanographic phenomenon of coastal upwelling occurs in the adjacent sea; a low rainfall (100-300 mm); high air temperatures (28-35 °C) and relative humidity (75-77%); as well as the action of the winds in a northeast direction (4.0 m/s-5.0 m/s during the drought and 2.0 m/s-3.0 m/s during rains); which result in high evaporation throughout the year (3430 mm), which exceeds precipitation by more than 10 times (Cumana *et al*. 2000, López-Monroy & Troccoli-Ghinaglia 2014). These lagoons only receive a slight entry of freshwater, from two intermittent runoffs, which drain in its southern part during the rainy season (June-November), when the wind speed is very low (Herrera & Febres 1975, Bello *et al*. 2016). Regarding the physicochemical characteristics of the waters of the lagoon system, temperature values have been recorded between 36.6 to 34.4 ºC, pH between 4.55 and 7.65, dissolved oxygen between 6.98 and 7.08 mg/l, and salinity between 32.00 to 70.67 PSU (Todelo *et al.* 2000, Prieto *et al.* 2009, Pérez *et al.* 2012, Jiménez-Ramos *et al*. 2019). Even somewhat high salinity values (38-40 PSU) have been found in waters outside the lagoon system, west of Chacopata (Lara-Rodríguez *et al.* 2015). This gives this lagoon ecosystem the typical characteristics of a negative or hypersaline estuary (Cervigón & Gómez 1986, Potter *et al*. 2010, Tweedley *et al.* 2019).

Samplings

The specimens were provided by fishermen from the town of Guayacán on the Península de Araya. These fishermen use hanging nets, placed in front of the roots of the red mangrove (*Rhizophora mangle*), in different internal sectors of the Chacopata Lagoon (Fig. 1B). The fishing period was always between 6:00 p.m. and 6:00 a.m. The captured specimens were labeled and refrigerated for transport and analysis in the laboratory.

Specimen analysis

For the identification of the specimens, the keys and descriptions of revision works of marine and estuarine fish were used, as well as of the Cichlidae family in Venezuela (Luengo 1970, Lasso & Machado-Allison 2000). Specialized works on the group of fish known as "*Tilapias*" were also consulted (Trewavas 1982, 1983; Skelton 1993, Lamboj 2004). Reference specimens were deposited in the fish collection of the Museo de Historia Natural La Salle, Caracas, Venezuela, under number MHNLS 26188.

RESULTS AND DISCUSSION

On November 21, 2017, a total of 17 specimens (between 180 and 230 mm SL) of *Oreochromis mossambicus* were captured, in an internal sector of the Laguna de Chacopata, between the 10°39'28.55" N - 63°49'09.40" W (Fig. 1B). Likewise, other specimens from the Laguna de Bocaripo were observed but not examined, because they were used by other fishermen for consumption. These specimens were only measured and not preserved (Fig. 2). Additionally, on March 15, 2023, about 19 specimens were captured, preserved and transferred to the MHNLS. A summary of the basic meristic and morphometric data of the examined specimens is presented in Table 1.

The examined specimens presented the morphological and chromatic diagnostic characters of the species (Trewavas 1982, 1983; Skelton 1993, Lamboj 2004): Long head and snout, with two to three scales in the interocular region and 9 to 12 scales in the nuchal region, up to the origin of the dorsal fin. Dorsal with 15-18 spines and 10-13 rays. Anal fin with 3 spines and 7 to 12 rays, 14 to 20 gill rakers on its lower arm. Fine teeth closely knit in several rows on both jaws. External ones in unicuspid or caninoid mature males. Caudal fin abundantly scaled in the initial two-thirds of its surface, with the final third free of scales. In females and juveniles, the color of the body is light gray, with cream on the ventral region, presence of two to five spots along the middle region, yellow iris, and dark gray fins. Males present a characteristic sexual

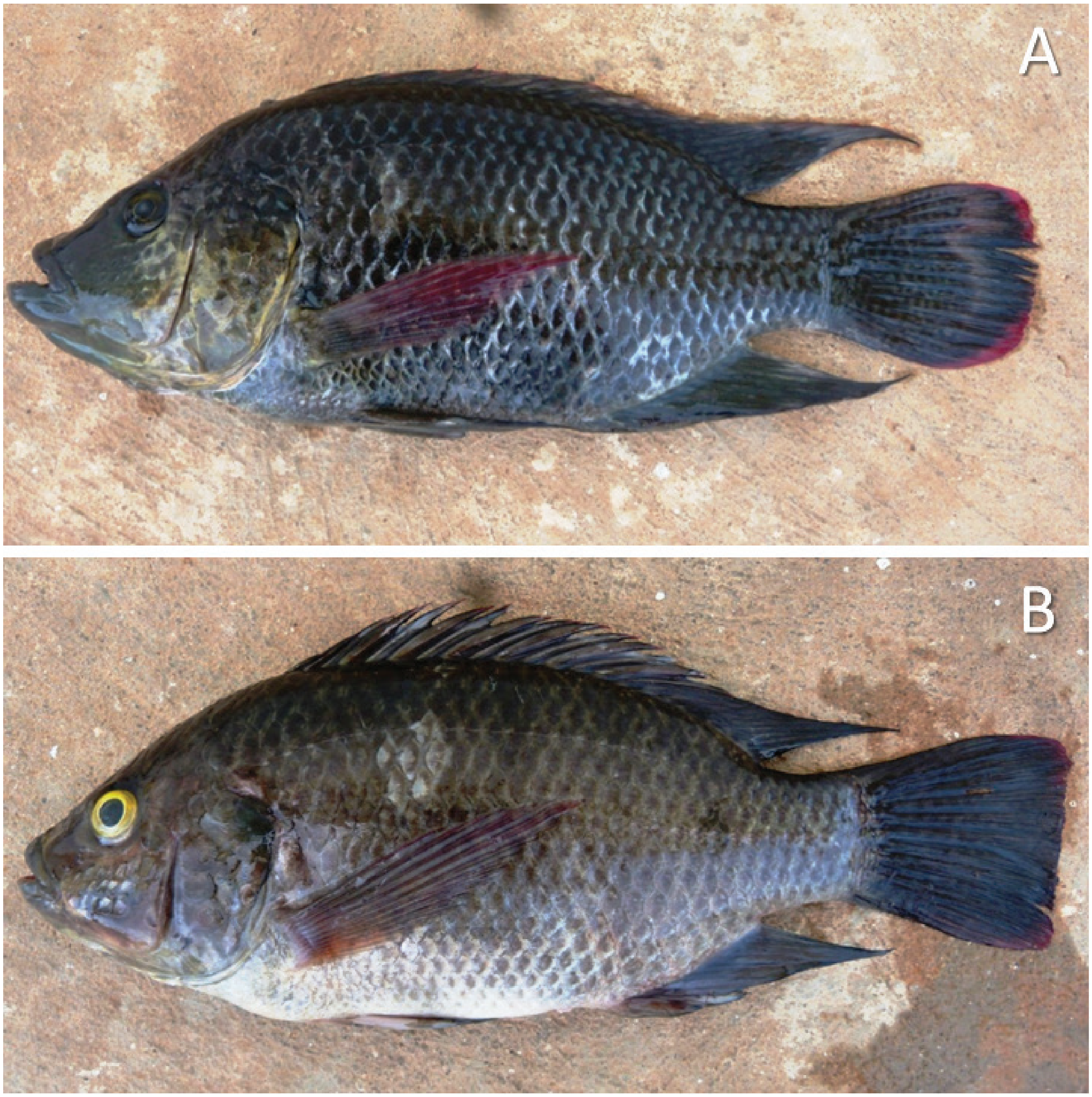

Figure 2. Specimens of *Oreochromis mossambicus* captured in the Chacopata and Bocaripo lagoon system, Península de Araya, Venezuela, in 2017. A. Male (215 mm SL); B. Female (200 mm SL). Photos: J. A. Bello P.

dimorphism expressed by the elongation of the lower jaw, which gives it a concave profile in the upper part of the muzzle. This modification is developed to attend reproductive activities, such as the excavation of nests at the bottom of the substrate. Likewise, the coloration is from a very dark gray to black throughout the body, including fins and irises, cheeks with yellowish tones, with red edges of the dorsal and tail fins, as well as the pectorals, in hyaline red tone (Fig. 2).

Oreochromis mossambicus is a species of the Cichlidae family, native to seven countries of the Southeast Africa, including the middle and lower basins of the Zambezi, Shire, Brak, Bushmans, Kwazulu-Natal and Limpopo rivers, coastal plains from the Zambezi Delta to Algoa Bay, in Mozambique, Malawi, Botswana, Zimbabwe, Eswatini, Lesotho, and South Africa (Philippart & Ruwet 1982, Trewavas 1982, 1983; Pullin 1988, Skelton 1993, Lamboj 2004, Firmat *et al*. 2013). For mainly aquaculture purposes, this species has been introduced in around 104 nations; of these, in at least 94 countries in the world (13 in Africa, one in Europe, 26 in Asia, 23 in Oceania and 31 in America [including Venezuela]), it has been successfully established (Welcomme 1988, Canonico *et al*. 2005, Froese & Pauly 2023).

Table 1. Morphometric and meristic data of the *Oreochromis mossambicus* specimens (n=19), captured in the Chacopata and Bocaripo lagoon system, Península de Araya, Venezuela (MNHLS 26188). Total Length (TL), Standard Length (SL), Dorsal Fin (DF), Anal Fin (AF), Pectoral Fin (PF), Caudal Fin (CF), Inter Ocular Scales (IOS), Pre-Nucal Scales (PNS) and Lower Gill Rakers (LGR).

	(n = 19)			
	Range		Mean	Mode
TL	129	254	191,5	
SL	99	200	149,5	
DF	XV, 13	XVI, 12		XVI, 12
AF	III,10	III,11		III,10
PF	13	14		13
CF	17	19		18
IOS	3	4		3
PNS	10	12		10
LGR	17	19		17

In Venezuela, this species was introduced from Trinidad Island (formally Republic of Trinidad and Tobago) in 1958, for the purpose of experimental aquaculture in the *Estación de Piscicultura, Ministerio de Agricultura y Cría*, located at El Limón, Maracay (endorheic basin of Lago de Valencia, central region of Venezuela), as indicated by some studies (Luengo 1963, 1970; Ramírez 1971, Welcomme 1988, Lasso-Alcalá 2001, 2003). From there, in 1964, 800 specimens were introduced into the coastal system adjacent to the mouth of the Río Manzanares, known as Laguna de Los Patos (coast of the city of Cumaná, eastern region of Venezuela: Fig. 1A); with the aim of experimental aquaculture by the *Universidad de Oriente* (Kahndker 1964, Carvajal 1965, Luengo 1970). Twelve years after this introduction, the disappearance of 75% of the fish and crustacean species previously known for said littoral ecosystem is noted (Aguilera & Carvajal 1976, Jiménez 1977). Subsequently, from the Laguna de Los Patos, where it still lives today, this species quickly dispersed and invaded the coasts of the Caribbean Sea in the Golfo de Cariaco (Nirchio & Pérez 2002, Gaspar 2008) and the Laguna de Punta Delgada (Marín *et al.* 2003) (Fig. 1A), thanks to its known broad tolerance to salinity (Philippart & Ruwet 1982, Trewavas 1982, Pullin 1988). In the Río Manzanares basin, it has invaded from its mouth or estuary to the middle system (Aricagua River, 250 m asl, pers. obs.), as well as the rainwater and wastewater collection systems of the city of Cumaná (Fig. 1A) (Nirchio & Pérez 2002. Pérez *et al.* 2003, Senior *et al.* 2004, Ruíz *et al.* 2005, Pérez *et al.* 2006b). Likewise, it has also been registered as introduced into the Río Barbacoas and its mouth (Chung 1990), as well as the Laguna de Campoma and mouth of Campoma river (Bonilla *et al.* 2010; pers. obs.), belonging to the Campoma and Casanay rivers basin, which empties in the eastern end or Saco at Golfo de Cariaco (Fig. 1). Additionally and recently, it has also been recorded in Laguna de Los Mártires, in the northwest coast of Isla de Margarita (Rodríguez *et al.* 2021; Fig. 1C). In this coastal lagoon, a generalized loss of biodiversity was found, due to the displacement and extinction of native species, where the disappearance of at least 85% of the fish community is estimated, as well as changes in the specific composition and the native community structure; and the dramatic reduction of the abundance, biomass and frequency of the native species.

In the hypersaline lagoon system of Chacopata and Bocaripo (Fig. 1B), the fishes constitute one of the relatively best documented groups, with five studies on their biodiversity, community structure and predation, which from 1983 to 2018 quantified about 47 native species of marine and estuarine habits (Oliveros & Martínez 1984, Acosta 1985, Meaño 1986, Valecillos 1993, Pérez *et al.* 2012, Rojas *et al.* 2018). Likewise, according to the local fishermen, the discovery of *Oreochromis mossambicus* during their fishing operations in this lagoon system dates from at least 2011. This coincides with our investigations, since in the samplings carried out between 2007 and 2008, this species was not recorded (Pérez *et al.* 2012). Although it is not fully certain, we believe that its introduction into this ecosystem has been intentional, due to its proximity to other systems where the species has already been introduced. Those nearby systems are the Laguna de Campoma and Campoma river mouth (27 km away), where it has been established since at least 2009, the Laguna de Punta Delgada (38 km away), since at least 2000 (Elizabeth Méndez, pers. com.) and Laguna de Los Patos (48 km away) since 1964, as stated at the beginning of this work (see Figs. 1A, B). In addition to the short distance between these ecosystems, another argument that supports this hypothesis of intentional introduction is the importance of this species for subsistence fishing of other communities of artisanal fishermen, such as those located on the coast of Cumaná and some coastal area communities of the Golfo de Cariaco. In those fishing communities, *O. mossambicus* is appreciated as a subsistence food and locally known by the common name of "*universitario*", since its origin in the region is recognized and attributed to the *Universidad de Oriente*.

Due to its tolerance of large variations in environmental parameters (*e.g.*: temperature, salinity, dissolved oxygen, pH, etc.), the Mozambique Tilapia has successfully colonized and invaded freshwater lakes, rivers, swamps, estuaries, coastal brackish lagoons, coral atolls, hypersaline desert lakes and hot springs where it has been introduced throughout the world (Trewavas 1983). Some authors indicate that it is a common species in closed estuaries and coastal lagoons (Blaber 1997), but generally absent in permanently open estuaries and open seas (de Moor & Bruton 1988). Contrary to this, in Venezuela, it has been recorded in the mouths of rivers such as the Manzanares and Barbacoas, and open lagoons such as Los Patos, and Punta Delgada, as well as in the adjacent sea in the Golfo de Cariaco (Chung 1990, Nirchio & Pérez 2002, Marín *et al*. 2003, Gaspar 2008; Fig. 1A), Laguna de Los Mártires (Isla de Margarita: Rodríguez *et al.* 2021; Fig. 1C) and in the present work we recorded it in the open coastal lagoons of Chacopata and Bocaripo (Fig. 1B).

Also, *Oreochromis mossambicus* has been successfully introduced and established in other marine ecosystems. In the Greater Caribbean region (Caribbean Sea and Gulf of Mexico), just to name a some cases, this species is found introduced in coastal marine lagoons, river estuaries, internal salt ponds, and open bays on islands and coastal waters, for example the USA (Baker *et al.* 2004), México (Raz-Guzmán *et al*. 2018), Puerto Rico (Burger *et al*. 1992), Aruba, Curaçao and Bonaire islands (Debrot 2003; Hulsman *et al*. 2008), Trinidad Island (Joseph *et al.* 2022) and Tobago Island (Mohammed 2014), in salinities ranging from 5 to 39 PSU. In the Southeastern Caribbean Sea (Northeastern region of Venezuela), salinities between 0 and 38 PSU have been recorded at the mouths of the Manzanares and Barbacoas rivers, Laguna de Los Patos, Laguna de Punta Delgada, Laguna de Campoma, the Golfo de Cariaco (Fig. 1A) and Laguna de Los Mártires (Fig. 1C) (Carbajal 1972, Chung 1990, Nirchio & Pérez 2002, Marín *et al.* 2003, Gaspar 2008, Rodríguez *et al*. 2021). This corresponds in part to the hypersaline conditions (> 40 PSU) in which we found *O. mossambicus* in the negative estuary of Chacopata and Bocaripo, whose registered salinity values range from 32.00 to 70.67 PSU (Todelo *et al*. 2000, Prieto *et al*. 2009, Pérez *et al*. 2012, Jiménez-Ramos *et al*. 2019); the latter is one of the highest values recorded for this species in a natural ecosystem. This salinity is even higher than other hypersaline ecosystems (internal lakes) where this species has been introduced; such as the Salton Sea (lake), in California (USA), where maximum salinity is 44 PSU (Caskey *et al*. 2007). However, in its natural range, for example in Saint Lucia Lake, an originally open estuary in South Africa, Whitfield and Blaber (1979) indicated that *O. mossambicus* can tolerate gradual changes in salinity to 120 PSU. According to these authors, ecologically, owing to its freshwater origin, *Oreochromis mossambicus* has been classified as a highly Euryhaline species (tolerance of 0 to 36 PSU). It is very likely that its extraordinary adaptive plasticity to new marine and hypersaline ecosystems, although with certain limitations in some locations, is due to genetic characteristics such as epigenetic modifications or adaptive mutations (Pérez *et al*. 2006b).

It is important to state that the introduction, establishment and invasion of *Oreochromis mossambicus* has a series of implications and consequences, given other biological and ecological characteristics of this species of cichlid. Among these are its omnivorous and piscivorous predatory habits, moderate fecundity but with strong parental care of eggs and young (territorialism), and rapid population growth. Therefore, the ecological consequences from the introduced fish of this family are unpredictable (Lasso-Alcalá *et al*. 2014). Some of the consequences that have been observed with the native fauna of the 94 countries where *O. mossambicus* has been introduced and is established, are: The direct predation of eggs, larvae, juveniles and adults; interspecific competition; reduction of abundance and biomass; displacement and extinction of species; changes in the specific composition and trophic structure of communities; generalized loss of biodiversity in the ecosystem; destruction and alteration of habitat; hybridization with species of the same or relative genus (only in Africa); and transfer of parasites (Aguilera & Carvajal 1976, Jiménez 1977, Canonico *et al*. 2005, Gutiérrez *et al*. 2012, Firmat *et al*. 2013, Cassemiro *et al*. 2018, Wilson 2019, Rodríguez *et al.* 2021). For these reasons, *O. mossambicus* has been listed as one of the 100 most harmful invasive alien species in the world (Lowe *et al*. 2004).

Taking into account this panorama and the current knowledge about the fish diversity of the study area in this work, it is necessary to carry out a monitoring program of the lagoon system of Chacopata and Bocaripo to determine if this invasive species has caused a change in the taxonomic and/or structural composition of the community of fish and other organisms of this ecosystem. Likewise, the presence of this and other species introduced in different coastal lagoon systems of Venezuela where they have not been detected must be evaluated, since most of the studies (Weibezahn 1949, Mago 1965, Fernández-Yépez 1970, Gómez 1981, Heredia 1983, Cervigón & Gómez 1986, Jory 1988, Rodenas & López-Rojas 1993, Ramírez-Villarroel 1993, 1994a, b, López-Rojas *et al* 1996, Marín 2000; Andrés de Grado & Bashirullah 2001, Barreto *et al*. 2009), have been carried out more than 10 years ago. It is evident that the situation in these ecosystems must have changed. This situation is particularly disturbing if other antecedents are taken into account, since on the coasts of Venezuela, at least six other species of estuarine and marine fish (*Eleotris picta, Omobranchus sewalli, Butis koilomatodon, Gobiosoma bosc, Pterois volitans* and *Neopomacentrus cyanomos*) have been identified as introduced, some of them being strongly invasive (Pezold & Cage 2002, Lasso *et al* 2004, Lasso-Alcalá *et al*. 2005a, b, 2008, Lasso-Alcalá & Posada 2010, Lasso-Alcalá *et al*. 2011, 2019; Cabezas *et al.* 2020, 2022). Added to this is the recent invasion of the octocoral *Unomia stolonifera* (Alcyonacea, Xeniidae), native to the Pacific Ocean, which is seriously impacting the native species and coastal marine ecosystems of Venezuela (Ruiz-Allais *et al.* 2022), and is already beginning to disperse throughout the Greater Caribbean (Espinosa *et al.* 2023).

CONCLUSIONS AND RECOMMENDATIONS

Due to the previous experience of the negative impacts generated by this species in coastal lagoons of Venezuela (*e.g.*: Laguna de Los Patos and Laguna de Los Mártires), and its biological and ecological characteristics; its new introduction in other coastal marine ecosystems of Venezuela, as well as in the hydrographic basins of the country must be prevented. As a management measure for the species in the coastal lagoon system or negative estuary of Chacopata and Bocaripo, fishing and consumption of *Oreochromis mossambicus* is recommended to reduce its populations, for the conservation of native biodiversity and local resources. For this, permanent educational awareness plans must be established at different levels, as well as the development of different technological packages for the aquaculture of native species. For these activities, international financial support is needed, as well as their technical support.

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