



Identification of potential fish stocks and lifetime movement patterns of *Mugil liza* Valenciennes 1836 in the Southwestern Atlantic Ocean



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ABSTRACT

The mullet *Mugil liza* is the Mugilidae that lives southernmost in the western Atlantic Ocean. Knowledge about migration, movements and identification of stocks of this important fishery resource is scarce. Thus, we aim to study movement patterns and to identify the presence of different fish stocks in the southwestern region of the Atlantic Ocean, using cumulative otolith shape morphometric and microchemical analyses of *sagittae* otoliths. Specimens ($n = 99$) were obtained in four coastal areas: Paranaguá Bay in Brazil, Samborombón Bay, Mar Chiquita Coastal Lagoon, and San Blas Bay in Argentina. Otolith shape indices (circularity, rectangularity, aspect ratio, percentage occupied by sulcus, ellipticity and form factor) were used for stock identification analysis; and otolith microchemistry using LA-ICP-MS (Sr/Ca and Ba/Ca ratios chronological variation) was used for both the analysis of movement behaviors and the identification of fish stocks (otolith edge ratios). Morphometrical indices did not reveal a clear separation among areas. San Blas bay individuals presented otoliths tending to be longer than wider, with a more elliptic shape than the otoliths from other studied areas; also, this area did not share individuals with the most northern one, Paranaguá Bay in Brazil. The analysis of microchemical lifetime profiles revealed three types of behavior pattern: Type I: most frequent use of estuarine environments; Type II: a fluctuating behavior between estuarine and sea/high salinity waters; Type III: most frequent use of sea/high salinity habitats. Otolith edge analysis did not reveal differences among Sr/Ca and Ba/Ca ratios for the different areas. Thus, it cannot be assured that there is more than one stock in the studied region. *Mugil liza* revealed different environmental migratory behaviors in the Southwestern Atlantic Ocean showing a facultative use of estuarine waters; hence, the species appears to be mostly coastal with the use of low estuaries, as seen also by the Sr/Ca otolith cores ratios; differing from the general mugilid behavior previously described.

1. Introduction

Members of the family Mugilidae, generally known as mullets, are coastal marine fishes with a worldwide distribution including all temperate, subtropical and tropical seas.

The mullet *Mugil liza* Valenciennes, 1836 is the Mugilidae species that lives southernmost in the west Atlantic Ocean, its distribution range goes from the Caribbean Sea to northern Patagonia in Argentina (Garbin et al., 2014). It inhabits offshore and coastal waters, but also spends part or even their whole life cycle in coastal lagoons, lakes and/or rivers (González-Castro and Minos, 2016; Harrison, 2002; Heras

et al., 2009; Thomson, 1997).

M. liza has been previously confused with *Mugil cephalus* and *Mugil platanus* (Heras et al., 2016; Whitfield et al., 2012). *Mugil liza* range was believed to be found as far as South of Rio de Janeiro in Brazil (Heras et al., 2009), and *M. platanus* was assumed to be a different mugilid species with a southern distribution. Nowadays, it is established that *M. platanus* is a synonym of *M. liza* (Menezes et al., 2010). Even though there is a difference among samples of *M. liza* from Rio de Janeiro (23°S) and those from all Southern locations (São Paulo to Argentina) given by significant genetic differentiation (Mai et al., 2014a), the authors only recognized the presence of two different demographic

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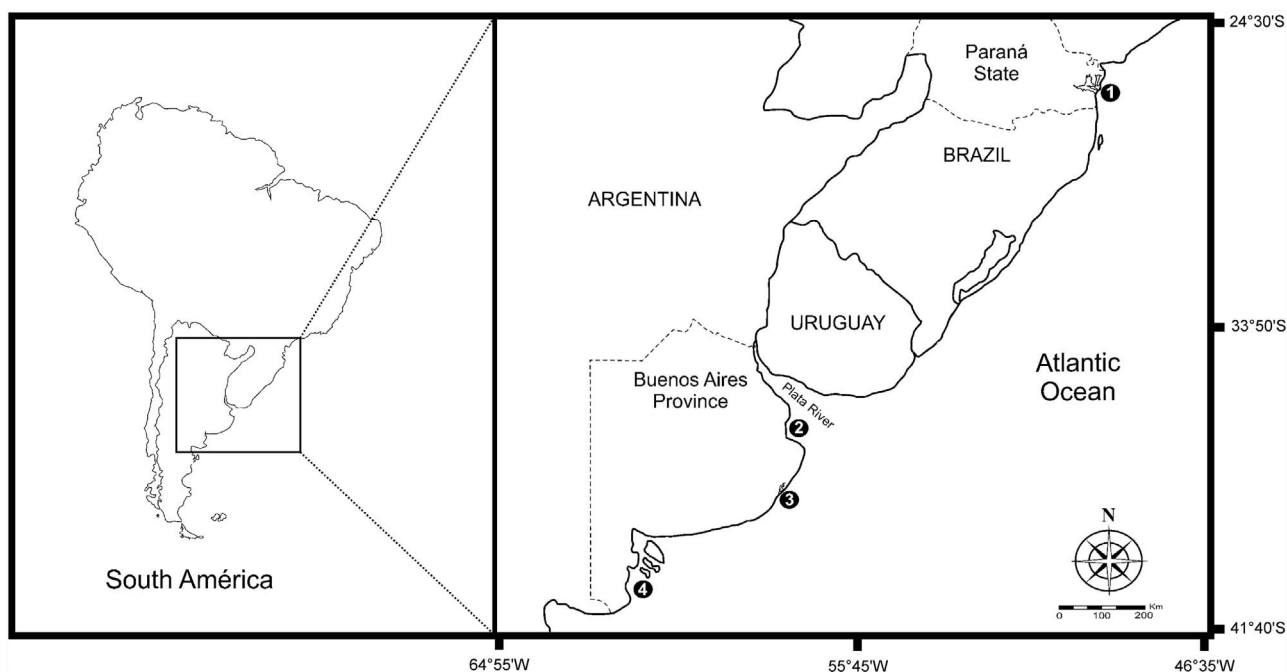


Fig 1. Location of *Mugil liza* sampling sites in the southwestern Atlantic Ocean: 1: Paranaguá Bay; 2: Samborombón Bay; 3: Mar Chiquita Coastal Lagoon; 4: San Blas Bay.

clusters of *M. liza* in the southwestern Atlantic Ocean. Referring to *M. cephalus*, both species have been proposed to be part of a species complex (Durand et al., 2012; Whitfield et al., 2012); however, since they have allopatric distribution ranges, both can be considered different species (González-Castro and Ghasemzadeh, 2016; Menezes et al., 2015; Whitfield et al., 2012).

Mugil liza is a commercially important species, in all of its distribution, mostly from artisanal catches supporting the local market and communities (González-Castro et al., 2009a; Mendonça, 2007). Particularly in Brazil, thousands of tons of this mullet are extracted from most of the coastal states of the country (IBAMA, 2007; Miranda et al., 2011). In Argentina, *M. liza* is part of a small-scale fishery, mainly in the northern coast of the Buenos Aires province, where it is used as food resource, or as fishermen sport (González-Castro et al., 2009a).

The several studies that have been carried out focused mostly in *M. liza* growth (Garbin et al., 2014; González-Castro et al., 2009a; Okamoto et al., 2006), reproduction (Albieri and Araújo, 2010; Albieri et al., 2010; Esper et al., 2001; González-Castro et al., 2011), abundance (De Araújo Silva and De Araújo, 2000), parasites (Alarcos and Etchegoin, 2010; Knoff et al., 1997, 1994); and importance as bioindicators of contamination (Hauser-Davis et al., 2012; Marcovecchio, 2004). However, there is a gap in the knowledge about migration, movements and identification of stocks of this important fishery resource.

Different methods have been used to study displacements and identify fish stocks such as mark-recapture, parasites, genetics and the analysis of calcified structures like scales and otoliths (Avigliano et al., 2014; Clément et al., 2014; Kerr and Campana, 2014; Sturrock et al., 2012). The research on otolith (complex calcium carbonate structures located in the inner ear (Campana, 1999)) has widened the knowledge of fish movements and migrations and stock identification of important commercial species (Avigliano et al., 2014; Avigliano et al., 2015a; Gillanders, 2005; Tabouret et al., 2010; Tracey et al., 2012). Morphometrical analysis of features like shape and contour (Lestrel, 1997) allows stock identification of species (Avigliano et al., 2015c; Sadighzadeh et al., 2014; Tuset et al., 2003b). Also, the study of the otolith chemical composition has been increasingly used to study fish displacements and identify fish stocks (Kraus and Secor, 2004; Schuchert et al., 2010; Tabouret et al., 2010). The analysis of elemental

signatures throughout otolith growth serves as a natural marker and can be used to reconstruct their lifetime movement patterns (Campana et al., 2000; Wang et al., 2010), due to the fact that chemicals deposited in the otolith represent a permanent record of the environmental conditions experienced by the fish at a particular time (Campana et al., 2000; Ruttenberg et al., 2005). Nowadays, Sr/Ca and Ba/Ca otolith ratios have been simultaneously used by some authors for stock and migration studies (Avigliano et al., 2015b; Schuchert et al., 2010; Tabouret et al., 2010). These elements vary between freshwater and seawater and are useful to understand diadromous fish migration behavior (Campana et al., 2009; Milton et al., 2008; Wang et al., 2010). Sr is correlated positively to salinity of water while Ba correlates negatively, hence the former element is strongly associated to marine waters while the second is associated to freshwater environments (Kraus and Secor, 2004; Elsdon and Gillanders, 2005; Miller, 2011; Tabouret et al., 2010).

The aim of this study was to identify the presence of more than one potential fish stock of *Mugil liza*, and to provide information on its movement patterns in the southwestern region of the Atlantic Ocean. To achieve this goal, cumulative analyses of morphometry and micro-chemistry of *sagittae* otoliths were performed.

2. Materials and methods

2.1. Study area and fish sample collection

Four coastal areas were selected in the Southwestern Atlantic: Paranaguá Bay in Brazil, Samborombón Bay, Mar Chiquita Coastal Lagoon and San Blas Bay in Argentina (Fig. 1). Adult individuals of *Mugil liza* were obtained from artisanal catches with gill nets or rods in the years 2012–2013 (Table 1). In all sampled areas, in spite of their different geomorphological features, sampling sites were located inside each estuary approximately at the same distance from the coastline (3 km). Also, no river outfall was located near sampling sites, so there were no local or temporal changes in water masses where fish were obtained. A total of 99 individuals were collected and taken to the laboratory. Standard length (SL in mm) was recorded and their *sagittae* otoliths were removed. After extraction, otoliths were dried and stored for further use.

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