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Discrimination analysis of phenotypic stocks comparing fish otolith and scale shapes

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ABSTRACT

The effectiveness of discrimination of phenotypic stocks was compared between otolith and scale shapes for *Mugil curema* specimens collected at five different locations in the Gulf of Mexico and two locations along the Pacific coast during two consecutive years. Geometric morphometric methods were used to determine the discrimination among locations using seven and 22 landmarks for scales and otoliths, respectively. The cross-validated discriminant analysis by location correctly classified 43.2 and 40.2% based on shape variables (Principal Components scores) for otoliths for all locations jointly, while for scales the classification percentages were 48.7 and 47.4% for the first and second years, respectively. Classification results improved when the discrimination analyses were carried out for pairs of locations, with 51.4 to 82.6% for otoliths and 72.7 to 97.1% for scales. The analysis was run for two consecutive years and the results for both years were best for the scales. Thus, fish scale shape offers a straightforward, non-destructive, accessible, quick and inexpensive method to trace fish phenotypic stocks.

1. Introduction

Stock recognition is essential in fisheries management since it is the basic unit of dynamic models designed to implement appropriate management measures for sustainability. Stock identification is an interdisciplinary field that involves the identification of self-sustaining components within natural populations, and is a central theme in fisheries science and management (Cadrin et al., 2005). It is therefore very important to understand multi-stock commercial fisheries, as different stocks may react differently to exploitation (Campana and Casselman, 1993).

Morphometry is widely used to identify phenotypic fish stocks as it is strongly influenced by the environment and the habitats that fish use (Swain and Foote, 1999; Keating et al., 2014). Morphometry analyses provide a quantitative description of shape and outline that may be compared statistically by means of a Fourier analysis (Lestrel, 1997) or through the use of landmarks and Geometric Morphometric methods with good statistical power, preserving the geometry throughout the analyses and providing graphic visualizations of the statistical findings which may aid biological interpretation (Dryden and Mardia, 1998; O'Higgins, 2000).

Morphological and morphometric characters of otoliths constitute an important instrument for species identification, using sagittae otoliths collected from fossiliferous layers in archaeological sites or from food remains of bony fish predators (Tuset et al., 2008). In this sense, otolith morphometry has been widely used to differentiate species (e.g. Bani et al., 2013; Callicó Fortunato et al., 2014), as well as to identify stocks (e.g. Farias et al., 2009; Cañás et al., 2012; Treinen-Crespo et al., 2012; Avigliano et al., 2015). The use of otoliths for these purposes is well recognised and, although their use is labour and equipment demanding, their value is clear (Hong-Yi et al., 2010).

Scale morphology has been used to identify inland fish of North America (Daniels, 1996), as well as to prepare taxonomic keys for freshwater ecosystems of diverse regions such as California (Casteel, 1972), Britain and Ireland (Maitland, 2004). Fourier analyses of fish scales have been used to discriminate among stocks (e.g., Jarvis et al., 1978; Richards and Esteves, 1997; Poulet et al., 2005) and, in recent times, Ibáñez et al. (2007) applied geometric morphometric methods (GMM) to scales in order to identify genera, species and local populations within the Mugilidae. Garduño-Paz et al. (2010) also used fish-scale morphometrics and were able to discriminate among sympatric phenotypes of the Arctic charr (*Salvelinus alpinus*). Staszny et al. (2012) also differentiated gibel carp (*Carassius gibelio*) populations. Moreover, fish scale shape was used to identify geographic variants among the Lutjanidae (*Lutjanus*

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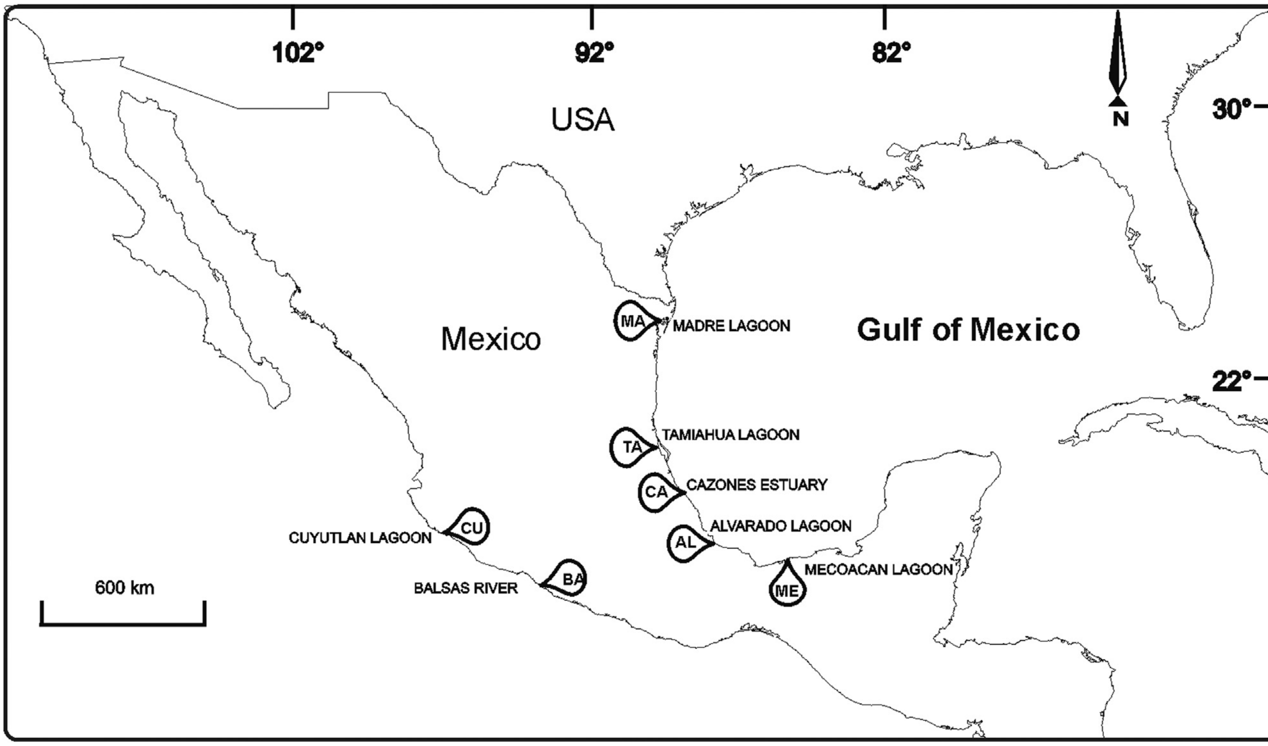

Fig. 1. Sampling locations in the Gulf of Mexico: Madre Lagoon, Tamaulipas (MA), Tamiahua Lagoon, Veracruz (TA), Cazones Estuary, Veracruz (CA), Alvarado Lagoon, Veracruz (AL) and Mecoacán Lagoon, Tabasco (ME). Locations in the Pacific coast: Cuyutlán Lagoon, Colima (CU) and Balsas River, Michoacán (BA).

argentiventris, L. *guttatus* and L. *peru*) of different geographic areas along the Pacific coast (Ibáñez et al., 2012).

Nevertheless, to our knowledge there are no studies that have compared the effectiveness of stock discrimination based on both structures, otoliths and fish scales, of the same specimens. Thus, this study compared the success of discrimination of phenotypic stocks using otolith and scale shapes in *Mugil curema* (Valenciennes, 1836) specimens collected at five different locations in the Gulf of Mexico and two locations along the Pacific coast during two consecutive years. One specific question was addressed: which structure, otoliths or fish scales, better discriminates among phenotypic stocks – this was assessed applying geometric morphometric methods to determine the discrimination among locations using seven and 22 landmarks for scales and otoliths respectively. *Mugil curema* was selected for this study as it is abundant, it is widely distributed along the Mexican coasts, and is very important economically as a source of roe.

2. Materials and methods

2.1. Fish scale and otolith collection

M. curema specimens were collected on similar days of 2009 and 2010, from commercial fisheries in Madre Lagoon (MA), Tamiahua Lagoon (TA), Cazones Estuary (CA), Alvarado Lagoon (AL) and Mecoacán Lagoon (ME) along the Gulf of Mexico (Fig. 1). Scales and otoliths were also collected in July 2009 from specimens captured from Cuyutlán Lagoon (CU) and the Balsas River (BA) along the Pacific coast of Mexico (Fig. 1; Table 1).

All specimens were adults with average total lengths (TL) of 287 ± 39 and 298 ± 21 mm, for the first and second year, respectively. No significant difference was found between years for TL ($p = 0.081$). In all cases, samples of approximately 50 specimens per geographic area were obtained for fish scales and among 32 to 50 for otoliths. Otoliths and scales were collected from the same fish, but sample size for otoliths were lower since some otoliths

Table 1
Sample sizes and sites of collection of fish scales and otoliths. Total length (TL) measurements for *Mugil curema* specimens.

Location		Year of collection							
		No. scales		No. otoliths		TL mean ± SD (mm)		TL range (mm)	
	Year	2009	2010	2009	2010	2009	2010	2009	2010
Gulf of Mexico	Code								
Madre Lagoon	MA	51	50	40	51	286 ± 12.2	296 ± 13.8	249–312	258–324
Tamiahua Lagoon	TA	46	50	37	51	299 ± 22.2	295 ± 22.9	230–350	244–332
Cazones Estuary	CA	50	50	35	48	307 ± 18.8	313 ± 26.7	245–347	235–360
Alvarado Lagoon	AL	50	50	37	50	276 ± 23.3	296 ± 21.5	224–339	246–339
Mecoacán Lagoon	ME	53	49	35	50	286 ± 42.3	294 ± 18.3	223–405	256–336
Pacific Coast									
Cuyutlán Lagoon	CU	50		32		226 ± 10.2		200–251	
Balsas River	BA	50		34		329 ± 22.4		261–372	
Total specimens		350	249	250	250				