Fisheries Research 186 (2017) 216–222

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Use of shell shape variation as an assessment tool in the southernmost razor clam fishery

Federico Márquez[a,b,*], M. Magdalena Trivellini[c,d], Silvina Van der Molen[c]

[a] LARBIM, IBIOMAR – CONICET, Blvd. Brown 2915 (U9120ACD), Puerto Madryn, Argentina
[b] Universidad Nacional de la Patagonia San Juan Bosco, Blvd. Brown 3100, Puerto Madryn (U9120ACD), Chubut, Argentina
[c] IBIOMAR – CONICET, Blvd. Brown 2915 (U9120ACD), Puerto Madryn, Argentina
[d] Universidad Nacional de Córdoba, Av. Vélez Sarsfield 299, Córdoba (×5000JJC), Córdoba, Argentina

ARTICLE INFO

Article history:
Received 25 April 2016
Received in revised form 25 August 2016
Accepted 26 August 2016
Handled by A.E. Punt

Keywords:
Phenotypic stock
Landmarks
Shell shape variation
South America

ABSTRACT

Morphological variation provides a method for phenotypic stock differentiation at inter- and intra-specific levels. Various methods are used for the assessment of fishery stocks in mollusks; one of them is geometric morphometrics. We analyzed morphological variation in razor clams at ten fishing grounds, five from the Argentinean North Patagonian gulfs and five from Chile, and evaluated the occurrence of phenotypic stocks between Argentinean and Chilean fisheries, using geometric morphometrics methods. The Argentinean harvesting of *Ensis macha* is emerging, and represents a way to diversify the shell-fisheries in north Patagonia. Nevertheless, fishing and aquaculture play important roles for the Chilean economy. Various multivariate methods were applied to describe the differences among and between fishing grounds. We found significant differences in the average shell shape of individuals from either ocean, and these differences principally describe changes in the robustness of the shell. The average shell shapes differed among sites from the Pacific while those from the Atlantic Ocean did not show statistical differences. This study shows that geometric morphometric techniques are appropriate for the identification of phenotypic stocks in *E. macha*. Our results could be used for future resource management and to determine the origin of the product in razor clams from South America.

1. Introduction

Several native bivalve species are of commercial interest in the North Patagonian gulfs, and are the basis of an important artisanal fishery. These include the Tehuelche scallop (*Aequipecten tehuelchus*), the purple clam (*Amiantis purpurata*), the mussel (*Mytilus sp.*) and the ribbed mussel (*Aulacomya atra*), which used to be captured in the 1970's using dredges, but are now fished mostly by diving (Orensanz et al., 2007). Recently, the razor clam (*Ensis macha*) represents an important alternative for artisanal fishermen divers to diversify the shellfish catches. Although the Patagonian region as a whole supports exploitation of fisheries such as deep-water hake and Patagonian red shrimp, artisanal exploitation of shellfish occurs primarily in San Matias and San Jose gulfs. In Argentina, a fishery for *E. macha* began at the start of 2000, but it has never been established as a regular fishing activity (Morsán and Ciocco, 2011). However, Chile is a country with important shell-fisheries along its highly productive coast, and one of the most important shellfish resources from the south-central harvesting areas is *E. macha* (SERNAPESCA, 2014). These geographical scenarios represent an optimal model to study "phenotypic" stocks (Booke, 1981). A phenotypic stock is a group of individuals with similar growth, mortality, and reproductive rates (Booke, 1981), which are exploited in a specific area. For fishery stock assessment, morphologically distinct populations should be modeled and managed as separate management units (Cadrin and Friedland, 1999, 2005; Cadrin, 2000, 2014). Therefore, establishing such units plays an important role in defining management measures for the shellfish resources at different geographical scales (intra-country and inter-country), but also would allow us to make a commercial tag with the origin denominations of the catches. The differentiation of food products by their particular qualities, such as their extraction/production and environmental features, is a useful tool to detect and avoid deliberate, as well as unintentional, substitution of different species and to reinforce labeling regulations (Fernández-Tajes et al., 2010). Knowing the origin of the catches would allow the industry to follow traceability, and facilitate commercial prod-

* Corresponding author at: LARBIM, IBIOMAR – CONICET, Blvd. Brown 2915 (U9120ACD), Puerto Madryn, Argentina.
E-mail address: fede@cenpat-conicet.gob.ar (F. Márquez).

http://dx.doi.org/10.1016/j.fishres.2016.08.027
0165-7836/

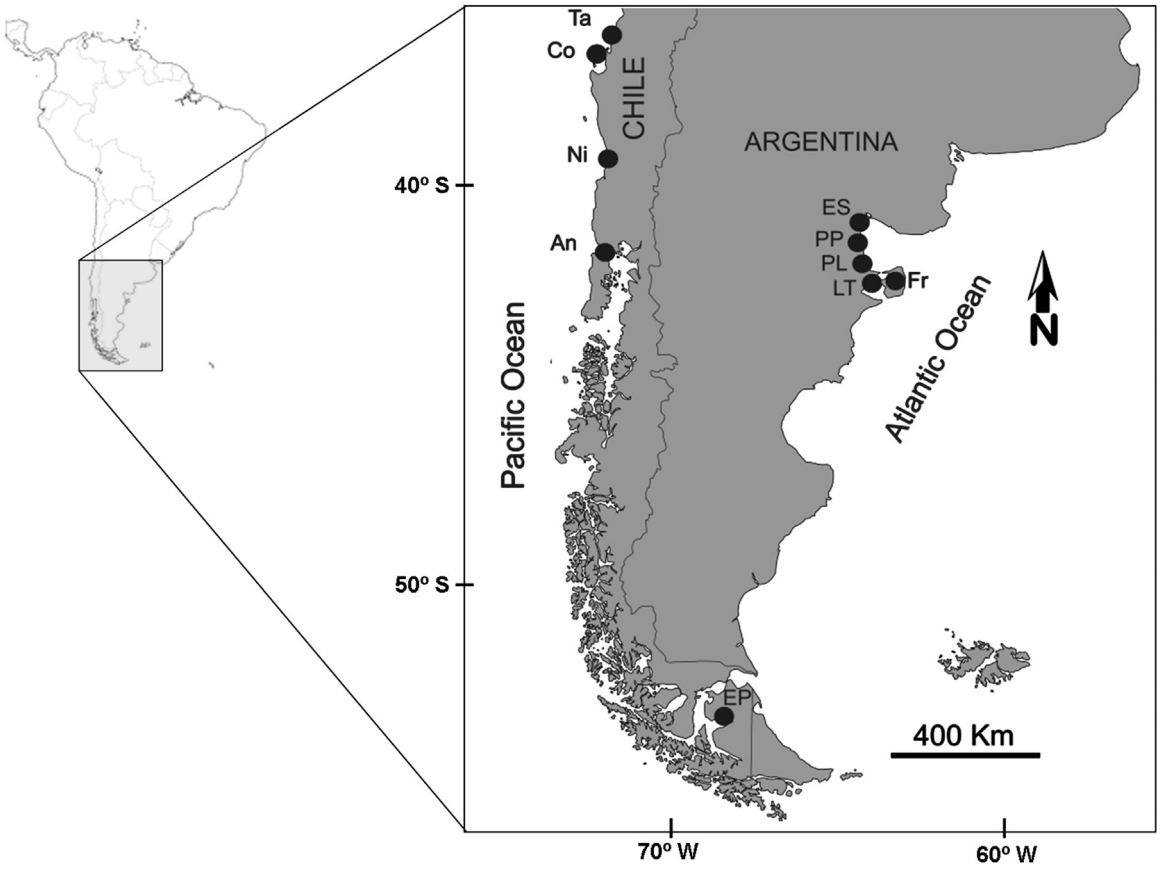

Fig. 1. Sample sites location. Sites codes from the Atlantic to Pacific oceans: ES: El Sotano; PP: Punta Pozos; PL: Puerto Lobos; LT: La Tapera; Fr: Fracaso; EP: El Porvenir; An: Ancud, Ni: Niebla; Co: Concepción and Ta: Talcahuano.

uct placement in new markets (Martínez Ruiz and Jiménez Zarco, 2006; CoFeCyT, 2008).

In addition to being an integral component of modern fisheries assessment (Begg et al., 1999) phenotypic stock identification is essential for the understanding the populations dynamics of a species in an ecological sense. Mollusks are an excellent target group for shell shape variation studies, since they have hard and stable shells (Rufino et al., 2006). The use of shell shape variables for phenotypic stock identification seems to be a realistic alternative for discrimination between groups since it corresponds to the most conspicuous portion of the body and presents high variability (Rufino et al., 2013; Márquez et al., 2010). Previous studies have reported that shell morphologic variation has been successfully used for phenotypic stock discrimination between marine bivalve species with similar shapes (Costa et al., 2008, 2010; Rufino et al., 2006), or between populations of the same species (Rufino et al., 2013; Márquez et al., 2010; Palmer et al., 2004). In the recent years, there has been an increasing interest in phenotypic stock studies using geometric morphometric methods (Cadrin, 2014). Geometric morphometrics (GM) is defined as the study of the shape variation and its covariation with other variables (Bookstein, 1991; Dryden and Mardia, 1998). GM techniques can be divided into two main groups, those that use Cartesian coordinates, in two or three dimensions, of homologous reference points (landmarks) and those based on object outlines. One of the main advantages of GM is that size and shape can be analyzed separately. Another advantage is that results of multivariate analysis can be visualized graphically (showing both the magnitude as well as the direction of change) since the implicit nature of geometric shape information is not lost during the analysis (Adams et al., 2004).

The razor clam *E. macha* (Molina 1782) is a burrowing bivalve that inhabits sandy and muddy bottoms of shallow subtidals. This species offers a good opportunity to study the phenotypic stocks of marine clams since it has a wide distribution: from Caldera (27°) to Magellan Strait (55°) on the Chilean coast, reaching San Matías gulf (40°) on the Argentinean coast (Lasta et al., 1998; Osorio, 2002). However, fishing on this species in the Atlantic Ocean is recorded only in two gulfs (SMG and SJG). However, in the Pacific, the catches of *E. macha* is an important fishing activity and is concentrated in Corral, Golfo de Arauco and Magallanes region (Lepez Gárcia et al., 2011).

Patterns of morphological variation in *E. macha* shells were compared between fishing grounds in Argentina and Chile using geometric morphometric techniques to determine whether there are phenotypic stocks.

2. Methods

2.1. Sample processing

A total of 518 individuals (130–180 mm of shell length) were collected using scuba diving from ten populations: five from the Atlantic (Argentina) and five from the Pacific Ocean (Chile) (Fig. 1; Table 1). Once the soft parts had been removed, a photograph of the left shell was obtained together with a scale of 1 cm^2. Shells were placed with the concave side upwards on a plasticine base to prevent a pitching and/or rolling effect and to match the height of the scale (Zelditch et al., 2004). Pitching refers to the movement in the anterior-posterior direction along the transverse axis, rising and falling, and rolling refers to the rotation along the longitudinal axis (dorsal-ventral direction). It is important to check that these