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Differences in shell morphology and internal growth pattern of the Patagonian scallop *Zygochlamys patagonica* in the four main beds across their SW Atlantic distribution range

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Abstract

Shell morphometry, internal shell growth patterns and growth rates of the Patagonian scallop *Zygochlamys patagonica* from four different beds across their SW Atlantic distribution range were compared. The northern beds (Uruguay, 36°17′S and Reclutas, 39°25′) showed lower shell height, length and shell mass than the southern populations (Tango B bed: 42°30′ and Beagle bed: 55°10′S). Mean height, length, and width increased following a N–S latitudinal gradient. Acetate peels revealed the presence of internal growth bands with alternating broad opaque and narrow translucent growth bands. In the Reclutas bed, the "cluster of translucent bands" representing external rings was formed mainly during winter at the same time of the higher gonadal condition index, and a regional decrease in food availability. The growth pattern observed for the first two or three growth bands was less pronounced than other growths bands, with sizes of these individuals corresponding to first maturity of the species. Thus, differences can be due to differential allocation of energy investment to shell production between juvenile and adult organisms. The internal growth patterns and maximum age differed between beds, with an increase in the maximum age from the N to the S (Uruguay bed: 13 years old, Reclutas bed: 14 years old, Tango B bed: 20 years old, Beagle bed: 21 years old). Our study provides evidence of variation of growth in *Z. patagonica* in the four main beds across their SW Atlantic distribution range, where a significant increase in H_∞ from N to S coincides with different internal growth pattern, maximum age and a trend toward higher von Bertalanffy k parameter in the northern beds.

Keywords: *Zygochlamys patagonica*; Scallops; Internal shell growth bands; Acetate peels; Age

1. Introduction

The Patagonian scallop *Zygochlamys patagonica* is distributed around the southern tip of South America reaching 42°S in the Pacific (Valladares and Stotz, 1996) and 35°50′S in the Atlantic within a depth range of 40–200 m (Waloszek and Waloszek, 1986; Lasta and Zampatti, 1981; Defeo and Brazeiro, 1994; Gutiérrez and Defeo, 2003, 2005; occasionally down to 960 m, Waloszek, 1991). In the Pacific, grounds occur in relatively shallow waters (less than 25 m; Andrade et al., 1991) while in the Atlantic the most important beds are located along the 100 m isobath (Defeo and Brazeiro, 1994; Lasta and Bremec, 1998) matching the location of three major oceanic frontal systems (Bogazzi et al., 2005). Variation of seasonal bottom temperature at this depth is less than 2–3 °C. In the northern range of their Atlantic distribution (i.e., Uruguay bed; 36°10′S) maximum values are during March to June (8.8, S.D. = 0.7 °C) and minimum during September to November (austral spring, 7.5, S.D. = 0.3 °C). In central beds (i.e., Reclutas; 39°20’S and Tango B beds; 42°30′S) the maximum are during early winter (May to July, 6.5, S.D. = 0.4 °C) and minimum during spring-summer (5.8, S.D. = 0.3 °C; Lomovasky et al., 2007). However, maximum annual sea-bottom temperature variation (4.5 °C) was observed on the Beagle bed (55°10′S, southern range of species

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distribution) with lowest values from September to December (5.7, S.D. = 0.7 °C) and maximum from January to May (8.5, S.D. = 0.4 °C; Baldoni and Guerrero, 2000; Lomovasky et al., 2007).

This scallop species is an important economic resource in the South Atlantic (e.g., Lasta and Bremec, 1998, 1999). The fishery started in Argentinean waters in 1996 (main grounds are between 38°S and 42°30′S) following surveys conducted during 1995 (Lasta and Bremec, 1998). Since then, the fishery has involved four 50 m long factory trawlers that process the catch on board, capturing up to 43.000 tonnes of commercial scallops in a year (e.g., year 2003, generating around 6.000 tonnes of adductor muscle; Lasta and Campodónico, 2004) for export market. Each bed is considered a management unit within two administrative sectors (south and north 39°30′S). Annually, a total allowable catch is established for each bed based on a model-based biomass estimates (Journel and Huijbregts, 1993). Between other management measures a series of closures within each main bed are imposed on the fishing activity to protect high density patches. However, a key parameter involved in this estimation is age, the possible variations across of which are unknown across the beds.

Indeed the determination of their individual age and thus growth rate, one of the key parameters for their stock assessment, has generated conflicting results probably due to geographic variations, but it has imposed a robust stock assessment. Most studies were based on observations of external shell surface growth lines (Waloszek and Waloszek, 1986; Lasta et al., 2001; Defeo and Gutiérrez, 2003; Gutiérrez and Defeo, 2005) and were performed on individuals from different locations across their latitudinal gradient (39°47′S–4°30′S; Fig. 1; Waloszek and Waloszek, 1986), in the Reclutas bed (39°20′S–35′S; Lasta et al., 2001) and in Uruguayan waters (35°50′S–36°40′; Defeo and Gutiérrez, 2003; Gutiérrez and Defeo, 2005). There were also analyses of internal shell structures in the chondrophores and ligaments (Waloszek and Waloszek, 1986; Bizikov and Middleton, 2002) from samples obtained along a latitudinal gradient extending from 39°47′to 54°30′S (Waloszek and Waloszek, 1986; Waloszek, 1991) and including the Malvinas (=Falkland) Islands (50°35′–47′; Bizikov and Middleton, 2002). The results from the Malvinas Islands beds obtained using external rings and chondrophores are different with substantial discrepancies regarding the estimates of maximum age (16 and 21 years old, respectively; Bizikov and Middleton, 2002), which may in part be due to the poor readability of external rings as individuals get older (see Bizikov and Middleton, 2002 and our observations). However, stable oxygen and carbon isotope ratio analysis from shells of this species from four large beds (Uruguay, 36°17′S; Reclutas, 39°20′S; Tango B, 42°30′; and Beagle, 55°10′S) together with the analysis of oceanographic parameters and condition indexes show that shell growth marks are formed annually during periods of higher water temperature where the energy input to gamete proliferation is the cause of decreased in shell growth indirectly mediated by food availability (Lomovasky et al., 2007).

The distribution of *Z. patagonica* in discrete beds along a large latitudinal gradient (approximately 20°) of the Atlantic coast is expected to generate different patterns of growth, aging, and/or morphometric characteristics. Indeed, Uruguayan populations (35°50′–36°50′S) show differences in growth rates decreasing toward the northern limit of the species distribution (Gutiérrez and Defeo, 2005). Therefore, it is important to identify possible differences between beds in order to perform bed-specific stock assessment. Thus, the purpose of this work is to evaluate if there are differences in morphometry and growth rates in the four main beds along their extended latitudinal distribution in the Southwestern Atlantic.

2. Material and methods

2.1. Sampling sites

Samplings of *Z. patagonica* ($n = 2047$) were performed in four beds, which from North to South (Fig. 1) are: Uruguay ($n = 106$, 36°17′S–53°49′W, depth = 108–109 m; samples obtained in April 2000 and June 2001), Reclutas ($n = 1346$, 39°20′S–56°W and 39°30′S–55°52′, depth = 101–110 m; monthly samples from January 2000 to December 2000), Tango B ($n = 200$, 42°30’S–59°05′W, depth = 96–118 m; samples obtained in March 2000 and July 2001) and Beagle bed ($n = 395$, 55°10′S–66°05′W, depth = 112 m; samples obtained in December 2003 and October 2004). The surveys were conducted using a 2.5 m wide dredge in all beds with the exception of the Beagle bed, which was sampled with a bottom otter trawl (foot rope of 22 m, net and cod-end of 10 cm mesh size). Previous information suggests that there are no differences in scallop size-selectivity between both fishing gears (Lasta and Bremec, 1997; Ciocco et al., 2006). A total of 24 trawls were made in the different beds. The initial and final positions of each trawl were registered (using GPS; precision: ±60 m). Depth records were obtained using a depth sounder (precision: ±1 m). Individuals were collected and frozen at −20 °C for laboratory measurements. In the laboratory, epibionts were removed by brushing the shell surface.

2.2. Morphometric relationship

For all collected individuals from the different beds we measured shell height (SH, umbo to the ventral margin), length (SL, anterior–posterior axis) and width (SW) (precision ±0.1 mm), and determined total mass without epibionts (TM), shell mass (SM), shell-free wet mass (SFWM), gonadal mass (GM), adductor muscle mass (AMM) and epibionts mass (EM; all parameters with precision ±0.01 g).

To compare the morphometric relationships between different beds, a full interaction ANCOVA model with subsequent Tukey multiple comparison tests (Zar, 1999) were used to evaluate effects on the relation between shell height (SH), length (SL), width (SW) and shell mass when assumptions of normality, homoscedasticity and parallelism were proved (Zar, 1999). To enhance overall data set homogeneity, we restricted the statistical analysis to the size range ≥24 to <66 mm shell height present at all beds. No comparisons were performed between other mass variables given the intra-annual variability in these parameters inside each bed (see Lasta et al., 2001).