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Research Article

Population dynamics and secondary production of *Darina solenoides* (Bivalvia: Mactridae) in the Río Gallegos Estuary, southern Patagonia

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ABSTRACT. The biology and ecology of *Darina solenoides*, an abundant bivalve of sandy sediments along Patagonian coasts, is poorly known. Here, we investigated the population dynamics and secondary production of this species in Río Gallegos Estuary (Southern Patagonia, Argentina, 51°35'S, 69°01'W). Sampling was conducted monthly, from April 2014 to June 2015, by collecting 10 samples from the intertidal fringe using a core of 10 cm inner diameter. The sediment was mainly composed of fine and very fine (77.5%) sand; total organic matter content was 1.8%. The average population density was 779.4 ± 56.4 ind m^{-2} the population was composed of four modal groups. The settlement of a new cohort occurred in April-May each year. The von Bertalanffy growth function was L_∞ = 49.4 mm; K = 0.5; the calculated lifespan was 4.2 years. Population somatic production was 80.6 g dry mass m^{-2} yr^{-1} and the production-to-biomass (P/B) ratio was 0.96. The observed high production supports the hypothesis that *D. solenoides* is an important resource for many marine species.

Keywords: *Darina solenoides***,** clam, soft substrates, macrobenthos, somatic production, key prey.

INTRODUCTION

The clam *Darina solenoides* (King & Broderip, 1832) is distributed along the coasts of the Atlantic and Pacific oceans in South America, from Bahía Blanca in Argentina to Puerto Montt in Chile (Signorelli & Pastorino, 2011). This species is abundant in soft substrates and has been identified as a potential fishery resource; at present, it is manually harvested from some coastal localities for self-consumption (Zaixso *et al.*, 2015). *D. solenoides* is the main prey of several migratory birds on the Patagonian coast in Argentina (Hernández *et al.*, 2008; Lizarralde *et al.*, 2010; Ferrari *et al.*, 2015) and Chile (Espoz *et al.*, 2008).

Río Gallegos Estuary (Patagonia, Argentina) has one of the largest tidal ranges in the world. The southern shore exhibits vast mud and fine-sand intertidal flats and saltmarshes with halophytic vegetation, mainly *Sarcocornia perennis* (Perillo *et al.*, 1996; Bortolus *et al.*, 2009). The estuary plays a key role as feeding and roosting site for several Nearctic birds (*Calidris fuscicollis, Limosa haemastica, Calidris canutus*, among others) as well as Patagonian species, such as *Charadrius falklandicus, Haematopus leucopodus*, and *Pluvianellus socialis* (Ferrari *et al.*, 2002).

In Río Gallegos Estuary, *D. solenoides* thrives in sandy substrates and is dominant in abundance in the middle intertidal zone (Lizarralde & Pittaluga, 2011). This clam species has been identified as a key prey of the Hudsonian godwit *Limosa haemastica* (Lizarralde *et al.*, 2010) and the Magellanic oystercatcher *Haematopus leucopodus* (Ferrari *et al.*, 2015). The available information on the species is scarce and only refers to some population aspects (size structure, density) and spatial pattern in intertidal environments (Pagnoni, 1997; Lizarralde & Pittaluga, 2011; Musmeci *et al.*, 2013).

The aim of this work was to analyze the population dynamics and secondary production of *D. solenoides* in the Río Gallegos Estuary, in order to contribute with information for future management strategies in the area.

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MATERIALS AND METHODS

Río Gallegos Estuary is located in southeastern continental Patagonia, Argentina (51°35'S, 69°01'W) and discharges into the Atlantic Ocean. It is a 45 km long macrotidal estuary, with a spring tidal range of up to 12 m (Perillo *et al.*, 1996). The local climate is cold, with a mean annual temperature of 7.2ºC and westerly winds of a mean speed of 35 km h^{-1}.

The sampling of *D. solenoides* was conducted at a site 20 km from the estuary mouth and 5 km upstream Río Gallegos city, which is located on the southern coast of the estuary (Fig. 1). Our monthly sampling from April 2014 to June 2015 consisted of 10 samples collected from the population, in the intertidal zone about 3 m above mean low water, where the highest abundance of the species has been previously recorded (Lizarralde & Pittaluga, 2011), using a core of 10 cm inner diameter, at a depth of 20 cm. Once a month, water temperature was recorded using a digital thermometer. Sediment samples were taken in April 2014; sediment grain size was analyzed through sieving and expressed as proportions, and a second sample was used to determine total organic matter content after combustion at 550°C for 5 h.

Clams were removed by sieving the sediment through a 0.25 mm mesh. They were counted and their shell length (L) was measured with a Vernier caliper (greatest distance along the anterior-posterior axis). Monthly dry mass (g DM m^{-2}) was measured directly by weighing the soft parts of the whole samples of clams after drying at 60°C until constant weight.

The relationship between shell measurements and age were analyzed using the von Bertalanffy growth function (VBGF) according to the exponential equation:

$$L_t = L_\infty[1-e^{-k(t-t_0)}]$$

where L_t is shell length (mm) at time t, L_∞ is the theoretical asymptotic length (mm), K is the growth coefficient and t_0 is the theoretical age (years). The ELEFAN I method from FISAT II (Gayanilo *et al.*, 2005) was used to adjust the VBGF. The different subroutines of the method were used to identify the VBGF that best fitted the monthly size-frequency data, using the R_n value as a fit criterion. The theoretical lifespan t_{max} was estimated by the inverse VBGF (Taylor, 1958):

$$t_{max} = [\ln L_{95\%}-\ln(L_\infty-L_{95\%})]/K$$

where $L_{95\%}$ represents 95% of the maximum length recorded during field sampling.

Relationships between shell length (L, in mm) and dry mass (DM, in mg) were studied on April 2014 on a sample of 500 individuals, by nonlinear regression analysis using the exponential equation:

$$DM = a\, L_t^{\,b}$$

where *a* and *b* are constants.

Somatic production was calculated by the mass-specific growth rate method (Crisp, 1984; Brey, 2001) from the size-frequency distribution obtained from all samples, the von Bertalanffy growth function and the size-mass relationship:

$$P = \Sigma N_i\, M\, G_i\ [\text{g m}^{-2}\ \text{yr}]$$

where N_i is the mean abundance (ind m^{-2}), M_i is the mean individual body mass in size class *i*, and G_i is the mass-specific growth rate:

$$G_i = b\, K\, (L_\infty /L_i)\text{-}1)\ [\text{yr}]$$

where *b* is the exponent of the length-mass relationship, K and L_∞ are parameters of the VBGF, and L_i is the mean length in class *i*.

To make the results comparable with production data from other studies, DM values were converted to ash-free dry mass (AFDM), using the conversion factor from Brey (2001).

RESULTS

Environmental variables

During the sampling period, mean annual water temperature was 7ºC, with maximum values of 11.5ºC in March (summer), and minimum values of 2ºC in August (winter).

The sediment in the study site was mainly composed of fine and very fine (77.5%) sands, medium sands (9.5%) and silt-clay (13%). Total organic matter content in sediments was 1.8%.

Population dynamics

The average population density was 779.4 ± 56.4 ind m^{-2} (n = 150 samples) (Fig. 2). No significant differences in density were observed among months (ANOVA, $P > 0.05$). The maximum density was 898 ind m^{-2} in April 2014. The average population biomass was 95.4 ± 17.6 g DM m^{-2} (n = 150) (Fig. 3). No significant differences were observed between months (ANOVA, $P > 0.05$). The maximum biomass was 127 g DM in spring 2014 (November).

The size frequency distribution (Fig. 4) showed a polymodal composition. The largest individual collected in the population was 46.70 mm in length, and the smallest was 0.30 mm. The growth parameters estimated by the routine ELEFAN I were: L_∞ = 49.4 mm and K = 0.5. The lifespan calculated (t_{max}) was 4.2 yr.

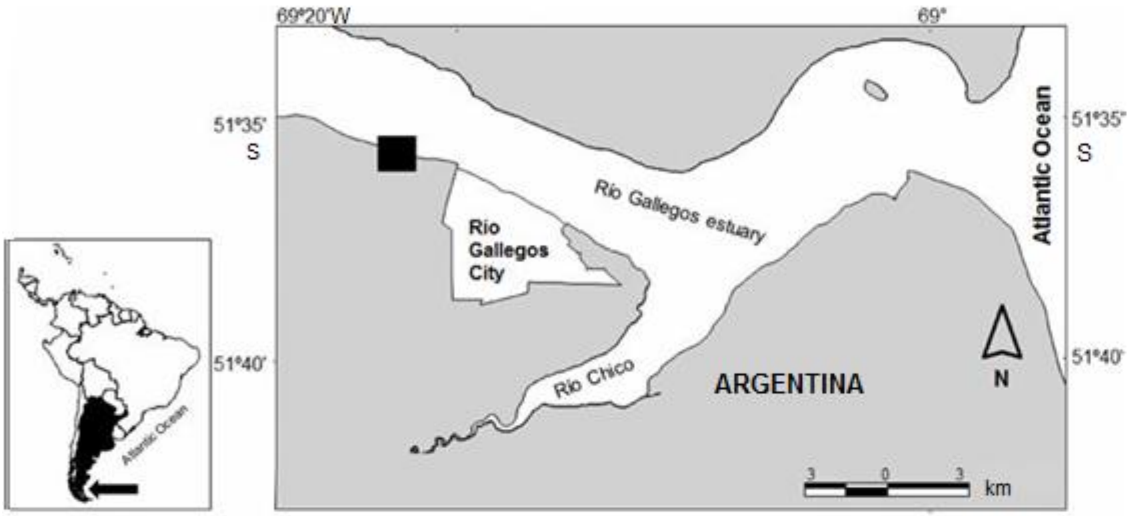

Figure 1. Study site (■) at Río Gallegos Estuary, Argentina.

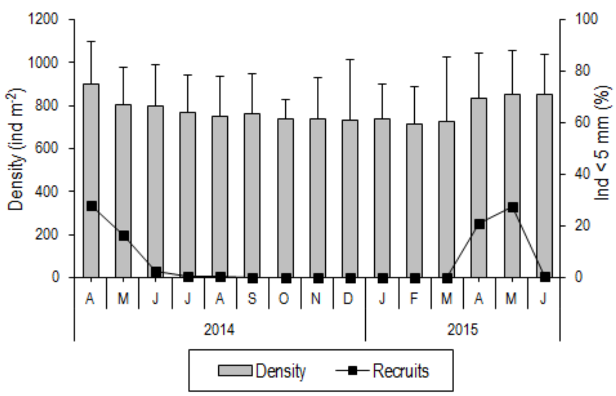

Figure 2. *Darina solenoides* population. Monthly density (+SD) and proportion of recruits (<5 mm).

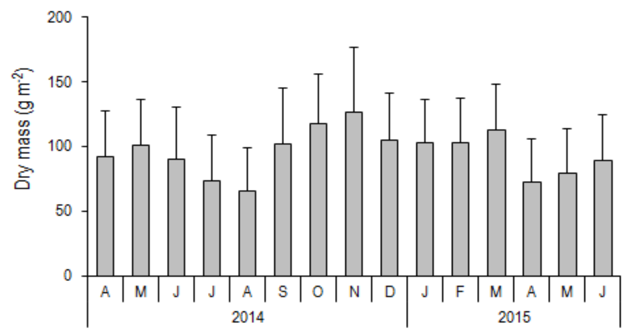

Figure 3. Monthly dry mass (±SD).

The individual dry mass of *Darina solenoides* was related to shell length using the equation: DM = 6.5 × 10^{-5} $L^{3.03}_{(mm)}$ (n = 500, R^2 = 0.85).

Secondary production

Individual production of *D. solenoides* depended on shell length, increasing steadily up to 35.2 mg at 33 mm shell length, and then decreasing (Fig. 5a).

Individuals between 33 and 35 mm in shell length made the greatest contribution to population somatic production, which was 80.6 DM g m^{-2} yr (Fig. 5b). Annual production-to-biomass (P/B) ratio was 0.96.

In terms of ash-free dry mass, annual production amounted to 66.99 g AFDM m^{-2} yr^{-1} (conversion factor 0.831 taken from Brey, 2001).

DISCUSSION

The studied *Darina solenoides* population lives in an intertidal environment characterized by sandy sediments with low organic matter content. Benthic assemblages dominated by *D. solenoides* are characteristic of Patagonian sandy shores from San Matías Gulf to the coasts of Tierra del Fuego, Argentina (Escofet, 1983; Pagnoni, 1997; Zaixso *et al.*, 2015). The species was also previously described as dominant in Río Gallegos Estuary (Lizarralde & Pittaluga, 2011).

The parameters of population dynamics presented in this work are the first data published for the species. Based on the maximum shell length observed and the theoretical size (L_∞ = 49.4 mm), we calculated a maximum lifespan of 4.2 years. Mean clam density ranged between 600 and 800 ind m^{-2}, this range being within the values reported for Bahía Lomas, Tierra del Fuego, Chile (Espoz *et al.*, 2008) and Península

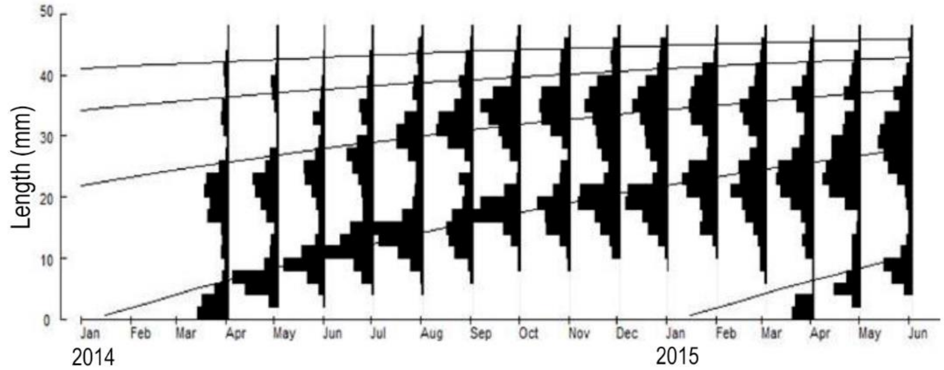

Figure 4. Growth curves (lines) of *Darina solenoides* estimated with the FISAT program from monthly length-frequency data (black histograms).

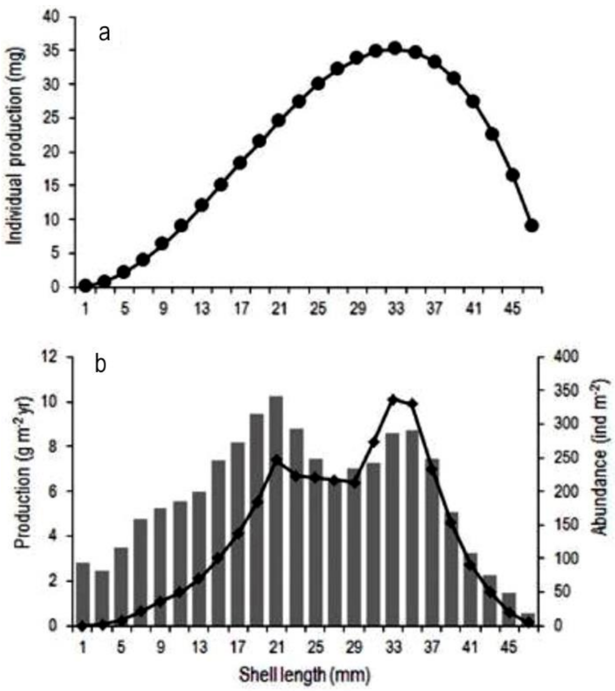

Figure 5. a) Individual somatic production for different shell length values in *D. solenoids*, b) shell frequency distribution (bars) and population somatic production (dots).

Valdés, Argentina (Musmeci *et al.*, 2013). Size distribution showed that the population is composed of four cohorts, with a unimodal recruitment pattern in autumn (April and May) each year. The only previous record of the month of recruitment is the study of Musmeci *et al.* (2013) in northern Patagonia, where individuals of less than 4 mm were recorded at the end of summer (March 2007). Since this information is essential to establish management criteria in a species of high fishing potential, it is necessary to study the gametogenic cycle simultaneously with studies of settlement and mortality to understand the clam population dynamics.

Somatic production of benthic organisms is an important component of energy flow and matter cycle in coastal ecosystems. Secondary production of bivalves has been used in a wide array of ecological studies, and its estimation is used to implement management plans of aquatic resources (Brey, 1990; Benke, 1993; Cusson & Bourget, 2005; Herrmann *et al.*, 2009). Somatic production of this *D. solenoides* population was found to be 66.99 g AFDM m^{-2} yr^{-1}, with a P/B ratio of 0.96. The low P/B ratio is characteristic of clam populations dominated by adults (Sprung, 1993; Sejr, 2002; Lizarralde & Cazzaniga, 2009). Although there are no published data of this species, the comparison with other bivalves from sandy coastal environments shows that the estimated population production is higher than values reported for other clams in Argentina: *Eurhomalea exalbida* (22.2 g AFDM, Lomovasky *et al.*, 2002); *Donax hanleyanus* (0.99 g, Hermann *et al.*, 2009); *Tellina petitiana* (18.8 g, Lizarralde & Cazzaniga, 2009); and *Mesodesma mactroides* (0.19 g, Herrmann *et al.*, 2011). This high production evidences a great contribution of *D. solenoides* to matter and energy flow in the estuary and its importance as a biological resource for other marine species, as well as the need to apply suitable management strategies for its conservation.

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