Population dynamic and secondary production of *Olivella minuta* (Gastropoda: Olividae) on Sandy Beach in Northeastern Brazil

Dinámica poblacional y producción secundaria de *Olivella minuta* (Gastropoda: Olividae) en una playa arenosa del noreste de Brasil

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Abstract

Olivella minuta (Link, 1807) is a common gastropod inhabitant exposed sandy beaches in Northeastern and Southeastern Brazil. The population biology and secondary production of this species were studied every 15 days from July 2004 to July 2006 on Meireles beach, state of Ceará, Northeastern Brazil. Growth and mortality were estimated from length-frequency data using computer-based methods. Life span was estimated by an inverse von Bertalanffy growth equation, considering t-max as 95% of the asymptotic length. Mass-specific growth-rate was used to calculate secondary production. Densities of *O. minuta* varied considerably during the period of study, with lesser values in the second year. The growth rate do not varied seasonally, with the 0.7 for two years. Mortality rates did not differ significantly between years (Z = 4.70 and 3.03 year–1, for the first and second year, respectively). Life span estimated was nearly 4 years. Estimated secondary production varied between 4.13 and 1.6 g AFDW m–2 year–1, while annual P/B ratio varied between 1.87 and 1.49.

Key words: gastropods, population structure, biomass, P/B.

Introduction

In an ecosystem the production is the way by which the energy becomes available to be transmitted from a trophic level to another one, being an important measure of the populations functioning and providing a quantitative base to understand the importance of a population in the community (Waters, 1977; Dolbeth *et al*., 2005). This parameter is in function of the population growth of the individuals that can supply subsidies to elucidate the transference of energy of the ecosystem, the rational handling of the biological resources (Waters, 1977; Downing, 1984).

Gastropods and bivalves are among the most conspicuous members of the macrofauna of exposed sandy beaches (Brown and McLachlan, 2006), and there are few studies relate to the population dynamics and the secondary production for this group in Brazilian sandy beaches (Caetano *et al*., 2003; Denadai *et al*., 2004).

Olividae caenogastropods inhabit sandy shores in tropical and subtropical regions of the world (Petuch and Sargent, 1986), measuring from 10 mm to100 mm in size (Smith, 1998). The genus *Olivella* Swainson, 1831 has 109 species distributed for the whole world. The Olividae Latreille, 1825 are represented in the Brazilian coast by 19 species of *Olivella*: *O. minuta*, *O. amblia* Watson, 1882, *O. ephamilla* Watson, 1882, *O. nivea* (Gmelin, 1791), *O. floralia* (Duclos, 1853), *O. petiolita* (Duclos, 1835), *O. mutica* (Say, 1822), *O. orejasmirandai* Klappenbach, 1986, *O. hyphala* Pimenta and Absalão, 2003, *O. formicacorsii*

Klappenbach, 1962, *O. riosi* Klappenbach, 1991, *O. tehuelcha* (Duclos, 1840), *O. watermani* Olsson, 1956, *O. arionata* Absalão, 2000, *O. careorugula* Absalão and Pimenta, 2003, *O. klappenbachi* Pimenta and Absalão, 2003, *O. olssoni* Altena, 1971, *O. plata* (Ihering, 1909) and *O. puelcha* (Duclos, 1840).

Olivela minuta inhabits the swash zone and surf zone of Brazilian sandy beaches from Ceará to Santa Catarina (Rios, 1994, 2009). This snail remains semi-buried moving by superficial excavation using the propodium; it also has a siphon short that protrudes above the substrate surface. It feeds on dead matter, small mollusks, crustaceans, polychaetes and algae. It uses small fragments of shells for fixation of their eggs. It is common and abundant in sandy areas beachrocks near the intertidal zone.

According to Rocha-Barreira *et al*. (2005), *O. minuta* is one of most abundant species in sandy beaches of Ceará. However, studies of this genus are sparse and mainly concern systematic (Klappenbach, 1964, 1965, 1966; Thomé, 1966; Absalão and Pimenta, 2003) and anatomy (Marcus and Marcus, 1959; Jurberg, 1970; Lopes, 1991; Borzone, 1995; Borzone and Vargas, 1999; Pastorino, 2007).

In the present study we describe the growth, mortality, life span and secondary production of *O. minuta* in a sandy beach of northeastern Brazil, based on a two years study.

Material and methods

Study area

The Meireles beach is located in the Mucuripe bay in the Fortaleza, Ceará, Brazil. This beach has beachrocks in the midlittoral zone extending to subtidal zone, with tide pools, and low hydrodynamic influence (Franklin-Júnior *et al*., 2005). Among beachrocks there are sandy areas. The tidal range can reach 3.2 m and the topography is smooth (Furtado-Ogawa, 1970).

Sampling and laboratory procedures

The population of *O. minuta* at Meireles beach (3°43’28.57” S; 38°29’33.50” W) was sampled every 15 days from July 2004 to July 2006, from swash zone always at low daily spring tide (Fig. 1). Ten samples of sediments spaced 5 m were collected in intertidal swash zone parallel to the waterline. Each sample was collected using a square of 0.25 m² and sieved on a 0.3 mm mesh. The sediment was fixed 4% formalin solution. In laboratory, the snails were separated and individual shell lengths were measured using a digital vernier caliper with 0.05 mm accuracy.

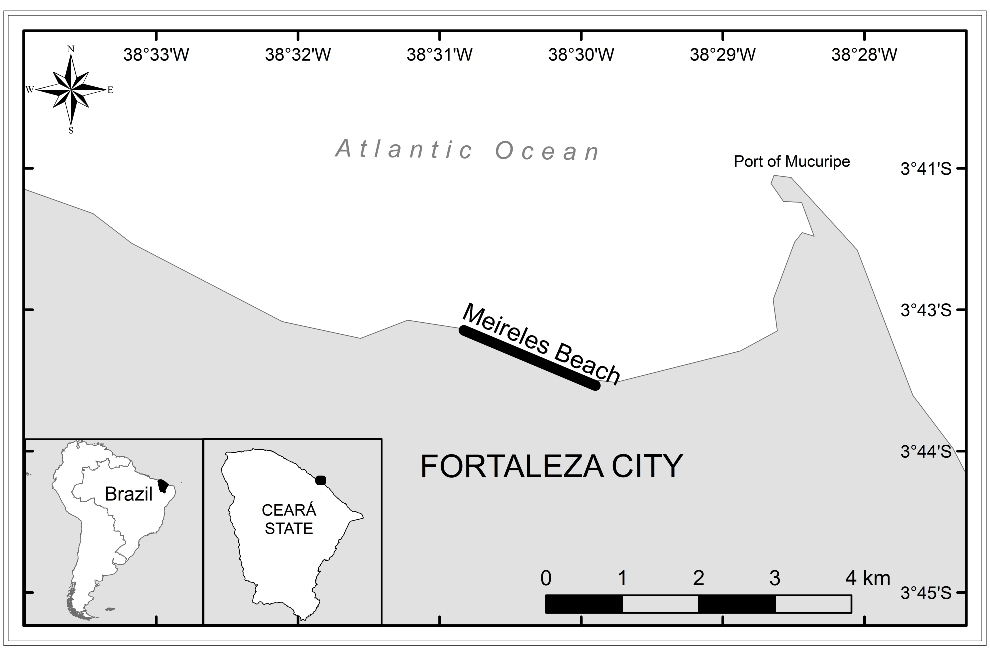

Figure 1. Map showing sampled area in the Meireles Beach, city Fortaleza - Ceará, Brazil.

Population parameters

The data were grouped monthly for method of the descriptive statistics. Growth and mortality functions were estimated from the monthly length measurements in the population (12 length-frequency samples with individual lengths grouped into 0.9 mm size classes). The routine Electronic Length Frequency Analysis (ELEFAN) of the package FAO-ICLARM Stock Assessment Tools (FISAT II) was used to fit a seasonal von Bertalanffy model (Gayanilo *et al*., 2005) to the set of restructured length-frequency samples. This curve has the form: $Lt= L_\infty \{1-e^{-K(t-to) + (CK/2\_)[(sen2\_ (t-ts)]}\}$,where *Lt* is length (mm) at time *t*; L_∞ is the theoretical maximum length that the species would reach if it lived indefinitely; *K* is the curvature parameter; *C* is a constant for the amplitude of oscillation in seasonal growth; *to* is age at zero length; and *ts* is the initial point of seasonal oscillation in relation to $t = 0$ and WP (winter-point, i.e. the period of growth reduction, expressed as a decimal fraction of the year).The graphical representation of this equation produces a curve that is evaluated through the goodness of fit index Rn (Gayanilo *et al*., 2005).

The instantaneous mortality rate (Z) was calculated by the single negative exponential model, using the length-converted catch curve method (Pauly *et al*., 1995) of the FISAT program (Gayanilo *et al*., 2005). Life span was estimated by an inverse von Bertalanffy growth equation, considering maximum length as 95% of the asymptotic length (King, 1995). The mean age was calculated by inverse of von Bertalanffy (Sparre *et al*., 1997): $ti = t_0 - (1/k)*\ln (1- Lti/ L_\infty)$, where mean age (Tm) is $Tm= \Sigma\ ti/n$ and *ti* is instantaneous age. The estimates of L_∞ and K were used to estimate the growth performance index (φ') (Pauly *et al*., 1984) of *O. minuta* using the equation: $\varphi' = 2 \log10 L_\infty + \log10K$.

Secondary production

Approximately 50 individuals considering the smallest and largest sizes observed were dried at 70°C for 48 h, weighed, and ashed in a muffle furnace for 4 h at 600°C. The relationship between shell length and ash-free dry weight (AFDW) of snails was estimated by linear regression analysis, with the data converted to natural logarithms in the equation: $\ln W= \ln a + b*\ln L$, where *W* is the mean ash-free dry weight per individual (g); *L* is the length of the size class (mm); and *a* is the intercept on the Y axis and *b* is the slope of the regression line. Production was estimated by mass specific growth rate (MSGR) of Crisp (1984) expressed as follows: $P=\Sigma\Sigma Ni*Wi*Gi*\Delta t$, where *Ni* is the mean number of individuals in size class *i*; *Gi* is the mass specific growth rate of size class *i*, *Wi* the mean weight of the size class *i* and *Δt* is the interval of time. Mass specific growth rate (Gi) can be obtained by: $Gi = b*K*(L_\infty - Li)/Li$, where *b* is coefficient relation between shell length and AFDW equation; L_∞ is the theoretical maximum length that the species would reach if it lived indefinitely; *K* is the curvature parameter; and *Li* is mean length in in size class *i*. Annual mean biomass was calculated as: $B = \Sigma\Sigma\ fi*Wi*\Delta t$. The turnover rates (P/B), derived of the ratio between annual secondary production (P) and annual mean biomass (B), was also calculated.

Statistical analysis

An analysis of covariance (ANCOVA) was used to compare mortality rates between years, using age as the covariate and an analysis of variance (ANOVA) for comparing variation mean shell length between the years. The Mann–Whitney U-test was used to compare biomass and secondary production between years. The *t*-test for independent samples by groups was used to verify variation density between the years. In all statistical analyses, a significance level of 5% was adopted. For these analyses the Statistica 7.0 Software was used.

Results

Population abundance, growth, life span, and mortality

During the study period 4.903 snails were collected and measured, 3.506 in the first year (July 2004–June 2005) and 1.397 in the second year (July 2005 – July 2006). The smallest individual was 0.5 mm and the largest 10.94 mm. Densities of *O. minuta* varied considerably during the study period with lesser values found in the second year. However, the population showed a peak of density during November 2004 and September/October 2005 producing significant difference between the years ($t= 2.27$, df = 22, $p<0.05$) (Fig. 2).

Estimates of growth indicated moderate seasonal oscillations (C= 0.2 and 0.001), with slowest growth rates occurring in March for the first year, and in February for the second year (Table 1). The values of the index of performances of the growth curve were similar between the years: 2.10 and 2.03, for the first and second years respectively (Fig. 3). There was no significance variation of the average shell length of the individuals between the years (ANOVA F = 3.54, df (1/ 22), p > 0.05).

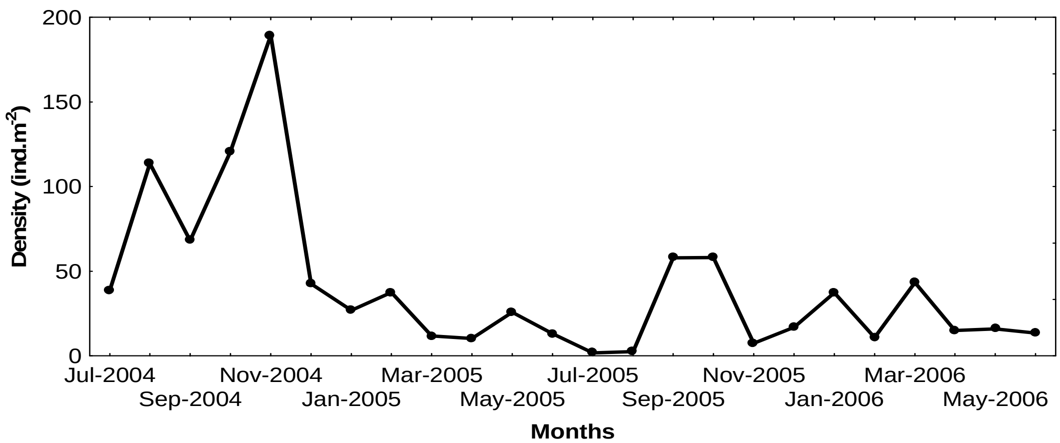

Figure 2. Monthly variations in density (ind. m^{-2}: mean ± SD) of *Olivella minuta* at Meireles beach from July 2004 to July 2006.

Table 1. Growth, mortality and life span estimates for *Olivella minuta* at Meireles Beach. L∞, asymptotic length (mm); K, curvature parameter (yr^{-1}); C, intensity of seasonal oscillation; WP, point of slowest growth rate in the year; Rn, goodness of fit index; Z, mortality rates (yr^{-1}); To, theoretical age in length zero; t_{max}, life span (yr) and Rn, index goodness.

Period	*L∞*	*K*	*C*	*WP*	*Z*	*To*	T_{max}	*Rn*
July 2004 – July 2005	13.5	0.7	0.2	0.25	4.7	-0.287	3.988	0.307
July 2005 – July 2006	12.45	0.7	0.01	0.3	3.03	-0.293	3.982	0.324

The recruitment was continuous and predominantly from March to September in both years studied. Recruitment peak was also observed in June in both years of study (Fig. 4).

The estimated life span (tmax) was 3.99 and 3.98 years, for the first and second years, respectively. The instantaneous mortality (Z) was 4.70 year–1 in the first year and 3.03 year–1 in the second year. Mortality rates showed not significantly different between years (ANCOVA F = 3.64, df (1/21), p > 0.05).

The population structure was characterized by unimodal adults presence in most months studied. The population of *O. minuta* has not reached advanced ages probably due to the high rate of instantaneous mortality. Only 1.70 % of the population was above the estimated average age. 27.3 % of snails were between the sizes 0.5 mm and 5.9 mm and the highest concentration (66.16%) between 5.9 mm and 9.05 mm (Fig. 5). The smallest individual found was 0.5 mm in size with an estimated age of 21.6 days and the largest individual found was 10.94 mm in size with an estimated age of 3.3 years. The average age of individuals of *O. minuta* was 1.18 years (N: 3.506 and SD: 0.43) from July 2004 to June 2005 and 1.55 years (N: 1.397 and SD: 0.42) from July 2005 to July 2006. Considering the two years studied, the average age was 1.28 years (N: 4903 and SD: 0.46).

Secondary production

The regression equation between length-ash free dry weight for *O. minuta* was LnW= Ln 5E-05 + 3.14 LnL (n=107, r=0.92, p < 0.0001) (Fig. 6). Estimates of mean annual biomass and secondary production by the mass-specific growth rate between years and size-frequency methods were slightly higher for the first year (4.13 g AFDW m^{-2} yr^{-1}) and lower for the second year (1.60 g AFDW

m^{-2} yr^{-1}), however they were not significantly different between years (U= 44.00, $p > 0.05$; U= 42.00, $p > 0.05$ for biomass and secondary production, respectively) (Fig. 7). The renovation rates (P/B ratio) were 1.87 and 1.49 for first and second year respectively. Because the predominance of adults the secondary production was higher in these classes (Fig. 8).

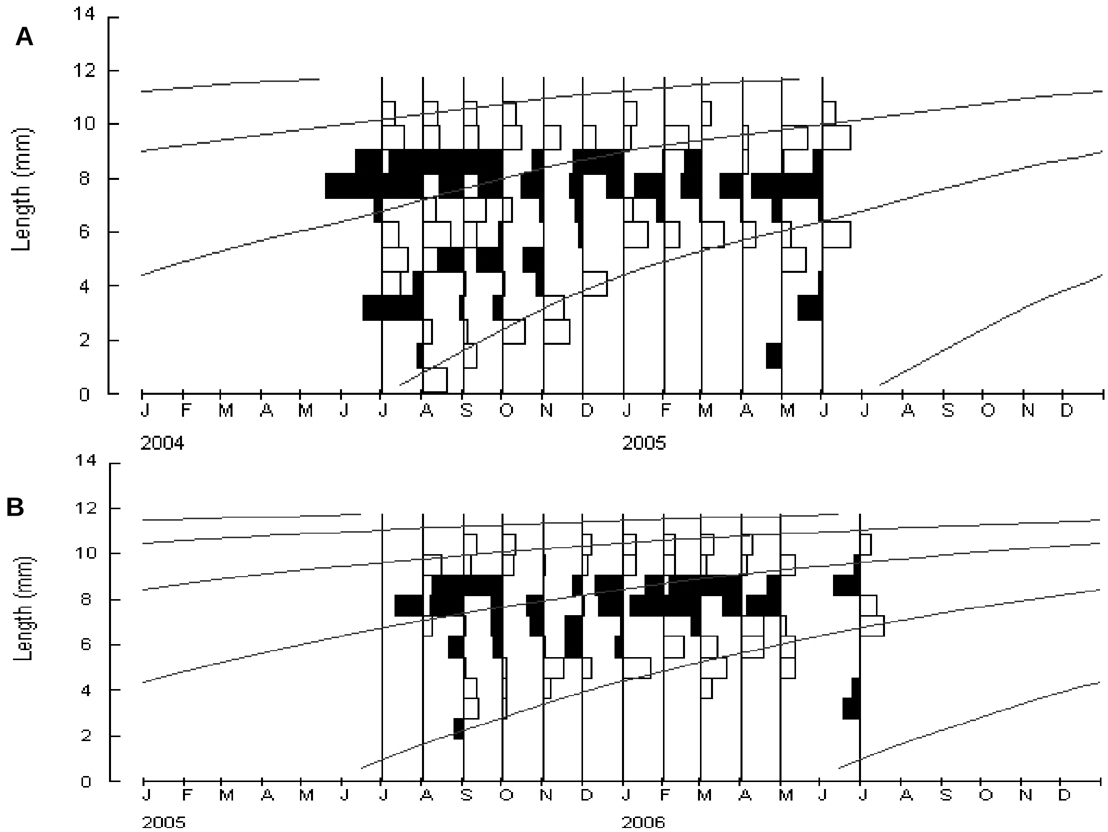

Figure 3. Seasonal growth curve fitted for *Olivella minuta* at Meireles beach. First year: July 2004–June 2005 (A), Second year: July 2005–July 2006 (B).

Discussion

In the present study there was low or no oscillation of the growth in function of the temperature. The coefficient of oscillation "C" had the maximum value 0.2, which features a maximum variation in temperature of 2°C/year. This was considered a low value, since the beach Meireles is located at 3°43'S, where the temperature variation is minimal. Thus, the oscillation of the growth of *O. minuta* was small, being the end of the rainy season (February, March and April) one of the factors responsible by the beginning of the reproductive process. According to Araújo *et al.* (2007) the population of *O. minuta* in Meireles has peak of reproduction in June. The period of fall or stopped of growth (WP) occurs in February and March before the gonadal maturation period.

The growth performance indices (φ') at two years of the study were very similar. This fact shows that the growth parameters estimated differ little among themselves and so there is no difference between the annual growth curve, but a continuity between the curves in the years analyzed.

The recruitment period started in March and followed to September in both years studied. Recruitment peak was observed in June in both years of study. This is probably due to input of nutrients in the system due to rainfall, increasing the availability of food for higher trophic levels. Part of this energy is used for the next reproductive event, through the production of gametes. In the dry season the lack of variation in salinity also contributes to the development of intracapsular *O. minuta*.

This was evidenced by Fernandes (2006) in the same population of *O. minuta*, with breeding during the year and peaks occurring in September and October 2004, corresponding to mid dry season in the state of Ceará.

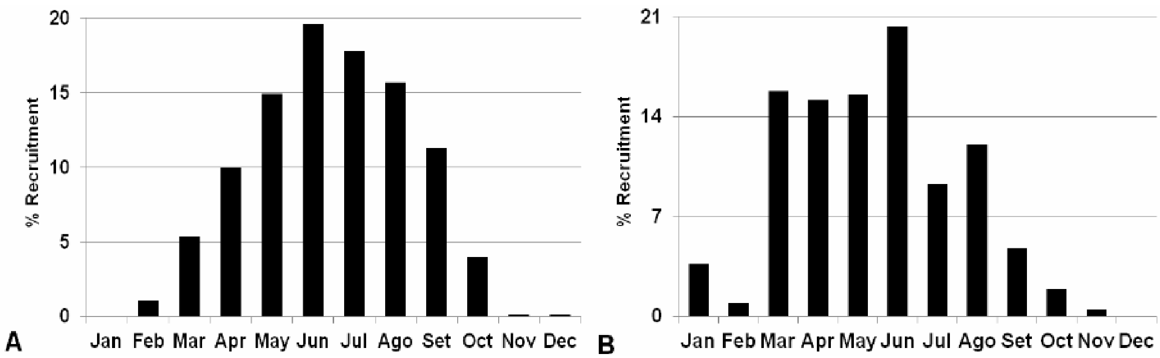

Figure 4. Standard recruitment of Olivella minuta at Meireles Beach during the period of July 2004 – June 2005 (A) and June 2005 – July 2006 (B).

According to Heller (1990), the growth of gastropods is related with size and the very small mollusks tend to have life expectancy between 2 and 3 years. The *O. minuta* life span (t max) is considered small compared to other gastropods, for example 17 years in *Zidona dufresnei* (Donovan, E., 1823) (Giménez *et al*., 2004) and 20 years in *Adelomelon brasiliana* (Lamarck, 1811) (Cledón *et al.*, 2005). Among the species of Olividae, the *O. minuta* life span is similar to *Olivancilaria vesica vesica* (Gmelin, 1791) ranging between 4.28 and 4.99 years (Caetano *et al*., 2003) and less than *Olivella biplicata* (Sowerby, 1825) that has between 8-12 years (Stohl, 1969) and *Oliva oliva* (Linnaeus, 1758) with approximately 10 years (Tursch *et al*., 1995).

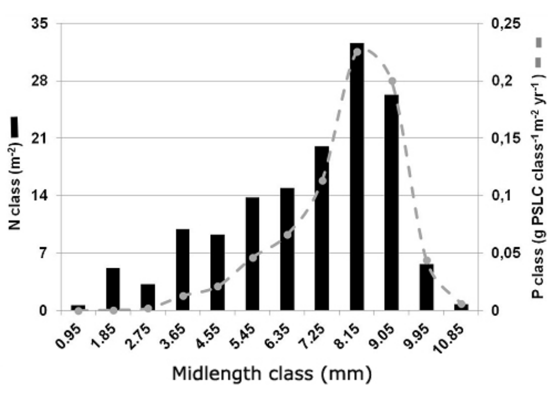

Figure 5. Distribution frequency (class N-1 m^{-2}) and secondary production (g SFWM $class^{-1}$ m^{-2} yr^{-1}) of *Olivella minuta* from July 2004 to July 2006 at Meireles Beach (r^2 0.95).

In this study, the mortality rate of *O. minuta* was moderate to high, showing higher mortality than *O. vesica vesica* with a maximum of 3.12 (Caetano *et al*., 2003). The mortality rate showed high levels in August 2004 and May 2005, after the reproductive event, as evidenced by Araújo *et al.* (2007), indicating that the great reproductive effort can cause death of the individuals due to the energetic expense. This mortality may also be related to predation of *O. minuta* by other invertebrates such as gastropods and starfishes (Rios *et al*., 1970; Nojima, 1988; Bitter, 2000; Ventura *et al*., 2001).

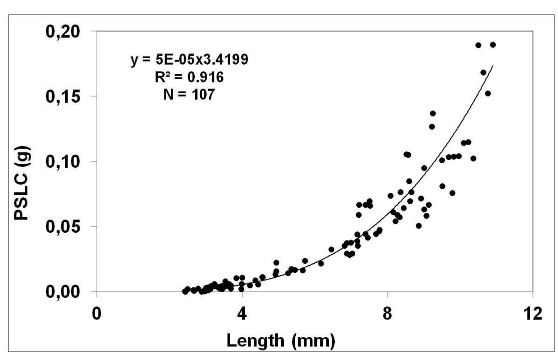

Figure 6. Ash Free Dry Weight and shell length of *Olivella minuta* at Meireles Beach.

The values of the secondary production for *O. minuta* ranged from 1.6 to 4.13 g AFDW m^{-2} yr^{-1}, lower than *Ventrosia ventrosa* (Montagu, 1803), estimated in 5.5 to 8.4 g AFDW m^{-2} yr^{-1} (Siegismund, 1982), *Melanoides tuberculata* (Müller, 1774), 12.09 g AFDW m^{-2} yr^{-1} (Dudgeon, 1986), *Chilina gibbosa* Sowerby, 1841 14.18 g AFDW m^{-2} yr^{-1} (Bosnia *et al*., 1990) and *Hydrobia ulvae* (Pennant, 1777) 8.0 g AFDW m^{-2} yr^{-1} (Sola, 1996). However, *O. minuta* has greater secondary production than *Bullia melanoides* (Deshayes, 1832), that is 1.06 g AFDW m^{-2} yr^{-1} (Ansell *et al*., 1978), *Bullia rhodostoma* (Reeve, L.A., 1847), 0.59 g PSLC m^{-2} yr^{-1} (McLachlan *et al*., 1979), *Turbo sarmaticus* (Linnaeus, 1758), 1.18 to 3.66 g AFDW m^{-2} yr^{-1} (McLachlan *et al*., 1980), *O. vesica vesica* 0.174 to 0.213 g AFDW m^{-2} yr^{-1} (Caetano *et al*., 2003) and *Cerithium atratum* (Born, 1778), 1,15 g AFDW m^{-2} yr^{-1} (Denadai *et al*., 2004).

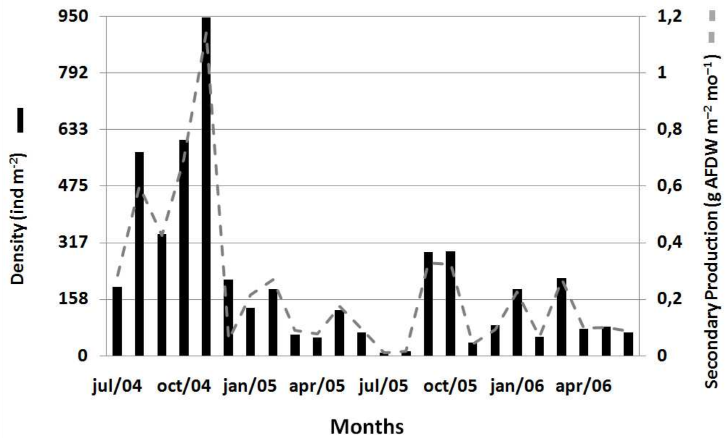

Figure 7. Annual secondary production and density of *Olivella minuta* at Meireles Beach, from July 2004 to June 2005 (r^2= 0.97).

As the population of *O. minuta* is dominated by adults, the secondary production is higher in sizes from 5.9 mm to 8.6 mm. There were two peaks of secondary production, August-November 2004 and September-October 2005. These periods probably corresponded to reproductive events of the population, when there was a high mortality due to the reproductive effort and the high mortality of recruits. These periods are also characterized by renewal and energy flow of the population through death and birth of individuals.

Populations dominated for older organisms, such as *O. minuta*, tend to have low values of P/B ratio (Urban and Campos, 1994; Noda, 1997), although has shown higher values than *B. rhodostoma*, 0.9 yr^{-1} (McLachlan *et al*., 1979), and *T. sarmaticus*, 0.48 to 0.69 (McLachlan *et al*., 1980). This is consequence of the decline of the mass-specific growth rate with age (Noda, 1997). According to Caetano *et al.* (2003), populations that show a high P/B ratio consist of small individuals, with a rapid growth rate and short life expectancy, while low *P*/*B* values are associated with large individuals with a slow growth rate and long life expectancy. *Olivella minuta* population has a high P/B ratio, with small snails, as well as high growth rate due to its continuous reproduction (Araújo *et al*., 2007) and reduced longevity compared with other gastropods species as *Buccinum undatum* Linnaeus, 1758, *Z. dufresnei*, *O. biplicata* and *O. oliva*.

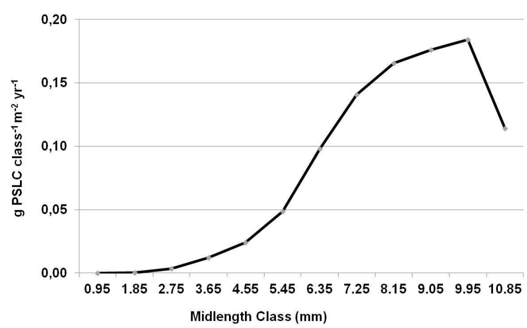

Figure 8. Secondary production (g SFWM ind^{-1} yr^{-1}) according to size class *Olivella minuta* (r^2= 0.90).

Acknowledgments

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