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### Age, growth and mortality in *Buccinanops globulosus* (Gastropoda: Nassariidae) from Golfo Nuevo (Argentina)

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## ORIGINAL ARTICLE

## Age, growth and mortality in *Buccinanops globulosus* (Gastropoda: Nassariidae) from Golfo Nuevo (Argentina)

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### Abstract

*Buccinanops globulosus* is a commercially exploited gastropod common in coastal waters of the Southwestern Atlantic Ocean. We determined the age and estimated growth and mortality rates of *B. globulosus* in a population from Golfo Nuevo (Patagonia, Argentina). Age was determined by counting opercular rings and growth was described by the von Bertalanffy function fitted to data of length-at-age. Mortality rate ( $Z$ ) was estimated by the linearized catch curve method. The maximum age was determined at 8 years. Growth parameters estimated for the whole population were  $TSL_{\infty} = 37.87$  mm,  $k = 0.33$  year<sup>-1</sup> and  $t_0 = -0.65$  year. Likelihood ratio tests indicated significant differences in asymptotic length and fitted growth models between sexes. Annual mortality rate (the first reported for the species) was estimated to be 0.34 year<sup>-1</sup> (0.49–0.20). Information on growth parameters of *B. globulosus* showed that  $TSL_{\infty}$  and the index of overall growth performance of the population studied here were intermediate compared to previously studied populations, thus indicating site-specific growth differences. Taking into account that the most common management strategy in gastropod fisheries is the use of a minimum size limit (MSL), we suggest that fishery measurements such as MSL for this species should be established only for small geographical scales.

**Key words:** Age, growth, mortality, gastropod, fishery management

### Introduction

Marine gastropods represent about 2% of the world mollusk catches (FAO 2009). In South America, the muricid *Concholepas concholepas* (Bruguère, 1789) and the strombid conch, *Strombus* spp., are the species of greatest commercial and social importance (Leiva & Castilla 2002). In Argentina, only three species of marine gastropods are the target of commercial fisheries: the volutids *Zidona dufresnei* (Donovan, 1823) and *Adelomelon beckii* (Broderip, 1836) (Giménez et al. 2004, 2005; Arrighetti et al. 2011), and the nassariid *Buccinanops globulosus* (Kiener, 1834) (Narvarte 2006), although many others have been identified as potential fishery resources (Bigatti & Ciocco 2008; Averbuj et al. 2010; Cumplido et al. 2010). In particular, the artisanal diving fishery for *B. globulosus* has been carried out since 2000 in a population where the

species reaches sizes up to 62 mm (Playa Villarino, Golfo San Matías) (Narvarte 2006). This species is exploited as a secondary resource in the fishery of the purple clam *Amiantis purpurata* (Lamarck, 1818) (Narvarte et al. 2007). Landings of *B. globulosus* have varied between 3 and 16 tons per year over the last five years (Río Negro Province, Fisheries Department). To date, there is no targeted commercial fishery on *B. globulosus* at other locations, although the species is harvested, especially during summer months, for family consumption or recreational purposes along its distribution.

*Buccinanops globulosus* is a common macrofaunal component of the Southwestern Atlantic Ocean (34–48°S). This species lives on sandy and muddy bottoms of coastal waters (up to 10 m), where it spends most of the time buried and forms dense aggregations (Scarabino 1977). As in

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other *Buccinanops* species, development is direct and females attach their egg capsules to the callus shell zone (Penchaszadeh 1971; Averbuj & Penchaszadeh 2010). Crawling juveniles emerge and live within the same area as adults, thus suggesting low dispersal capability (Penchaszadeh 1971). All these biological features may lead to overharvesting and local extinction if an extractive activity is performed, such as has been reported for other species with similar life-history traits, e.g. *Buccinum undatum* (Linnaeus, 1758) (Cadée et al. 1995; Valentinsson et al. 1999; Morel & Bossy 2004; Shelmerdine et al. 2007) and *Z. dufresnei* (Giménez et al. 2005).

Previous studies on *B. globulosus* have shown great variability among populations for many biological characteristics such as maximum size, size at maturity, fecundity and morphometrics of shell and radula (Narvarte et al. 2008; Avaca et al. 2010, 2012). Body size is an important component of the life history, representing a tradeoff between growth, reproduction and maintenance (Stearns 1992). Size variation between populations may reflect differences either in survivorship or in growth rates, and has potential implications for fishery management (e.g. establishment of a minimum landing size: Gendron 1992; Shelmerdine et al. 2007). The population of *B. globulosus* of Bahía Nueva may represent a new commercial fishing ground which is already exploited by tourists and for family consumption. There is, however, no information on the population characteristics of this species. The aims of this study were therefore to estimate the age, growth and mortality as the fundamental parameters to understand its population dynamics and to provide useful information for management purposes. Also, we discuss size structure and growth variation among different populations of *B. globulosus*.

## Materials and methods

### Sampling

Individuals of *Buccinanops globulosus* were captured monthly between March 2007 and August 2008 ( $N=6037$ ), except for May and July owing to bad weather conditions, in the intertidal–shallow subtidal area of Bahía Nueva, Golfo Nuevo (Argentina) ( $42^{\circ}46'S$   $65^{\circ}02'W$ ) (Figure 1). Biological bait (mainly fresh or thawed fish) was used to attract whelks on the seabed. Bait was left for at least a 20-min interval. Attracted whelks were collected by handpicking or SCUBA diving at low and high tides, respectively, brought to the laboratory in sea water and frozen at  $-18^{\circ}C$ .

At the laboratory, total shell length (TSL, mm; Figure 2A) was measured with digital calipers ( $\pm 0.01$  mm), and total wet weight (TW, g) was recorded with an analytical scale ( $\pm 0.01$  g) after slow thawing. The operculum was detached from the foot of each individual and then rinsed and stored in dry conditions for later analyses. A subsample of at least 50 individuals by sampling date were dissected, and sex was determined by the presence of accessory glands (capsule and albumen gland) in females and by its absence and the presence of a penis in males, taking into account that this population shows imposex, i.e. superimposition of male characteristics onto females (Bigatti et al. 2009).

### Population structure and sex ratios

Length frequency distributions (TSL) were calculated to study the size population structure of *Buccinanops globulosus* at Bahía Nueva. Comparisons for length distribution between seasons were performed by Kolmogorov–Smirnov tests (summer: January–March; autumn: April–June; winter: July–September; spring: October–December). Sex ratios were calculated, and the null hypothesis of a ratio 1:1 was assessed by Chi-square tests.

### Age determination

The operculum was used to determine the age of *Buccinanops globulosus* by counting the number of rings (Narvarte 2006). Following Kideys (1996), only opercula with very clear rings were taken into account. To supplement information of the youngest age class (0 age), we included data from individuals ( $n=25$ ) that hatched at the laboratory from ovigerous females collected in the field. These data were used in the estimate of the overall growth function and in the estimate of the growth function of each sex. The length (OL) and width (OW) of each operculum were measured with a digital caliper (Figure 2A). The number of rings of each operculum occurring on the ventral face was counted under a stereomicroscope ( $10\times$ ) (Narvarte 2006) (Figure 2B). In order to validate the periodicity of ring formation, the final portion (margin) of each operculum was checked and classified as finalizing a 'dark' (ring recently formed) or a 'clear' (irregular margin). The frequencies of each type of margin were recorded on a sample of at least 20 individuals per month over a year, except on May and July.

To assess the relationship between ring formation and temperature, sea-surface temperature (SST) was recorded in situ with a multiparameter probe (YSI 556 MPS) at the time of sample collection. Also, SST regimes based on estimations available

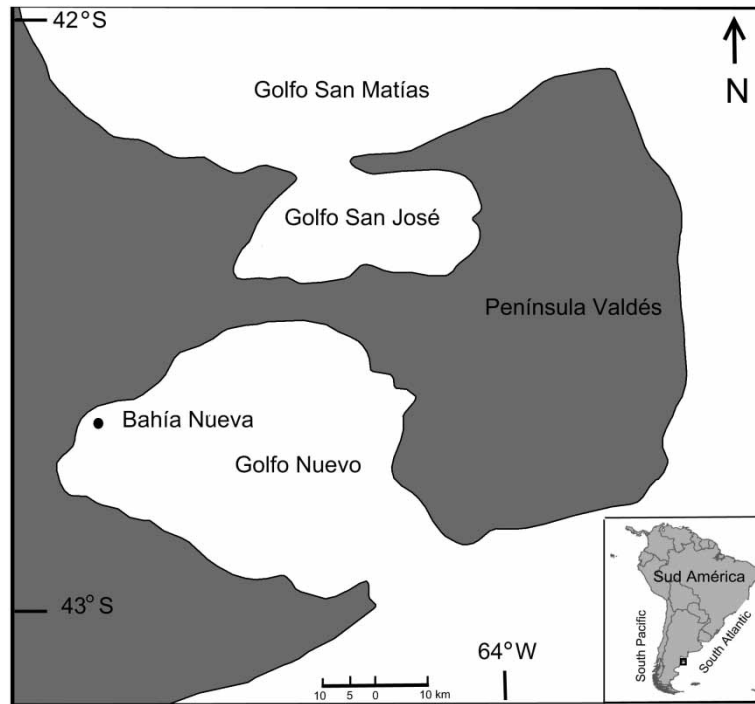


Figure 1. Sampling location of *Buccinanops globulosus* at Bahía Nueva in Golfo Nuevo.

in public access databases (single  $4 \times 4$  km grid cells closest to the point of interest; AVHRR Pathfinder 5, NOAA-NASA) were analysed for the 1994–2007 period at a selected geographic point ( $42^{\circ}32'S$ – $64^{\circ}52'W$ ).

#### Growth model

Data of individual size and age (based on operculum rings) were used to fit the von Bertalanffy growth function (VBGF):  $TSL_t = TSL_{\infty} * (1 - e^{-k*[t-t_0]}) + \varepsilon$ , where  $TSL_t$  is the shell length at age  $t$ ,  $TSL_{\infty}$  is the asymptotic total length (mm),  $k$  is the catabolic coefficient or growth constant ( $\text{year}^{-1}$ ),  $t_0$  is the theoretical age at which TSL would be zero and  $\varepsilon$  is an error term normally distributed. The parameters ( $TSL_{\infty}$ ,  $k$  and  $t_0$ ) were estimated following the maximum likelihood method (Kimura 1980; Aubone & Wöhler 2000).

Growth of males and females were compared by likelihood ratio tests (Cerrato 1990), under different null hypotheses,  $H_{01}: TSL_{\infty M} = TSL_{\infty F}$ ;  $H_{02}: k_M = k_F$  and  $H_{03}: \Theta_M = \Theta_F$ , where F and M indicate females and males, and  $\Theta$  is the vector of growth parameters ( $TSL_{\infty}$ ,  $k$  and  $t_0$ ). We also calculated the overall growth index  $P$  ( $P = \log(k * TSL_{\infty}^3)$ ) to assess growth performance between sexes. Overall growth performance was displayed in the form of an auximetric grid (Moreau et al. 1986; Pauly et al. 1996). Comparisons with other nassariid

species and other populations of *B. globulosus* were also carried out based on literature data.

#### Mortality

The instantaneous total mortality rate ( $Z$ ,  $\text{year}^{-1}$ ) according to the single negative exponential mortality model  $N_t = N_0 * e^{-Z*t}$  was estimated by the linearized catch curve method (Beverton & Holt 1956; Ricker 1975) according to  $\ln(N_t) = \ln(N_0) - Z * t$ . The catch curve was based on the size-frequency distribution of all the sampled individuals during the studied period. An age-at-length key was used to estimate the number of whelks at each age class (Bettoli & Miranda 2001). In order to avoid biases related to the subrepresentation of individuals of small size classes (not fully recruited) and of the oldest (rare) individuals, mortality rate was estimated from the age class with a maximum frequency and up to the oldest age class with a relative frequency greater than 5% (Van Den Avyle & Hayward 1999).

## Results

#### Population structure and sex ratios

The size range of collected individuals was 5.23–47.83 mm total shell length (Figure 3). Size-frequency distribution was unimodal with a mean total shell length ( $\pm$ SD) of  $25.43 \pm 6.83$  mm. Sex

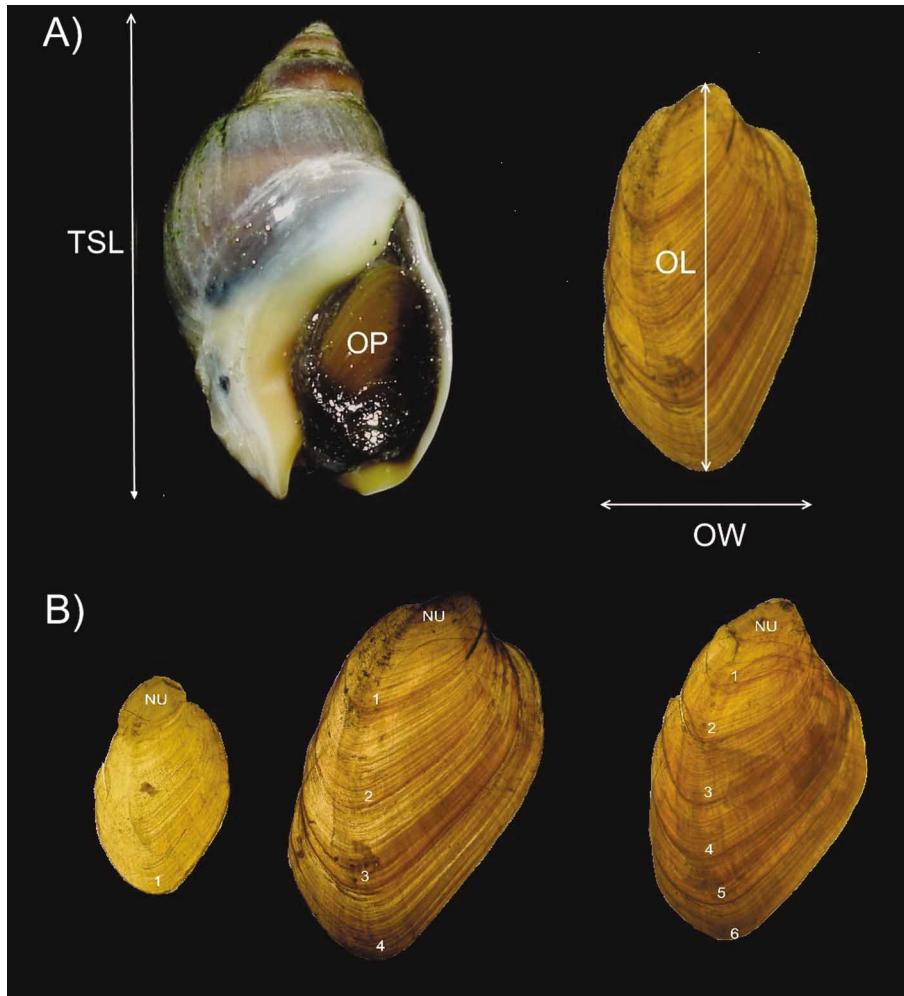


Figure 2. *Buccinanops globulosus*. (A) Morphometrics of the shell and opercula, and (B) opercula showing one, four and six rings completely formed (numbers). NU, nucleus (operculum present at birth); OL, operculum length; OP, operculum; OW, operculum width; TSL, total shell length.

could be determined for individuals larger than 16 mm in total shell length. The mean length of males was significantly smaller than that of females ( $24.16 \pm 4.26$  mm,  $n_M = 1338$ ;  $29.02 \pm 6.57$  mm,  $n_F = 2532$ ) ( $t$ -test;  $p < 0.05$ ). There were statistical differences in the length frequency distribution between seasons for almost all the study period, with the exception of autumn 2007 and winter 2007 (Kolmogorov–Smirnov,  $p < 0.05$ ).

The overall sex ratio was significantly different from 1 : 1 ( $\chi^2 = 184.19$ ,  $df = 1$ ;  $p < 0.0001$ ). For all the seasons, females outnumbered males (Figure 4). Chi-square test results and sample sizes for each sampling date were: 2007 summer:  $\chi^2 = 4.02$   $n_F$ : 114,  $n_M$ : 75; autumn:  $\chi^2 = 18.45$   $n_F$ : 302,  $n_M$ : 170; winter:  $\chi^2 = 68.11$   $n_F$ : 720,  $n_M$ : 340; spring  $\chi^2 = 14.52$   $n_F$ : 429,  $n_M$ : 285; 2008: summer:  $\chi^2 = 63.89$   $n_F$ : 531,  $n_M$ : 221; autumn:  $\chi^2 = 20.66$   $n_F$ : 248,  $n_M$ : 124; winter  $\chi^2 = 6.79$   $n_F$ : 188,  $n_M$ : 123; in all cases  $p < 0.05$ .

#### Age determination

A total of 678 opercula were used. Significant linear relationships were found between total shell length (TSL) and operculum length, and between TSL and operculum width ( $OL = 0.3536TSL + 0.0113$ ,  $R^2 = 0.95$ ;  $OW = 0.2107TSL - 0.3344$ ,  $R^2 = 0.94$ ). From the plot of monthly frequencies of opercular margins (Figure 5A) it can be observed that a dark ring is formed annually. Thus the presence of each pair of margins (clear+dark) represents one year of growth. The estimated ages, based on the number of opercular rings, ranged between 0 and 8 years for individuals ranging from 2.7 to 43.73 mm shell length. The individuals collected in the field that did not show complete formation of one ring were considered as age 0+.

Sea-surface temperature (SST) showed a clear seasonal pattern, with temperatures reaching minimum values in August (austral winter) (in situ:  $8.64^\circ\text{C}$ ; NOAA-NASA:  $10.56^\circ\text{C}$ ) and maximum values between January (in situ:  $22.10^\circ\text{C}$ ) and

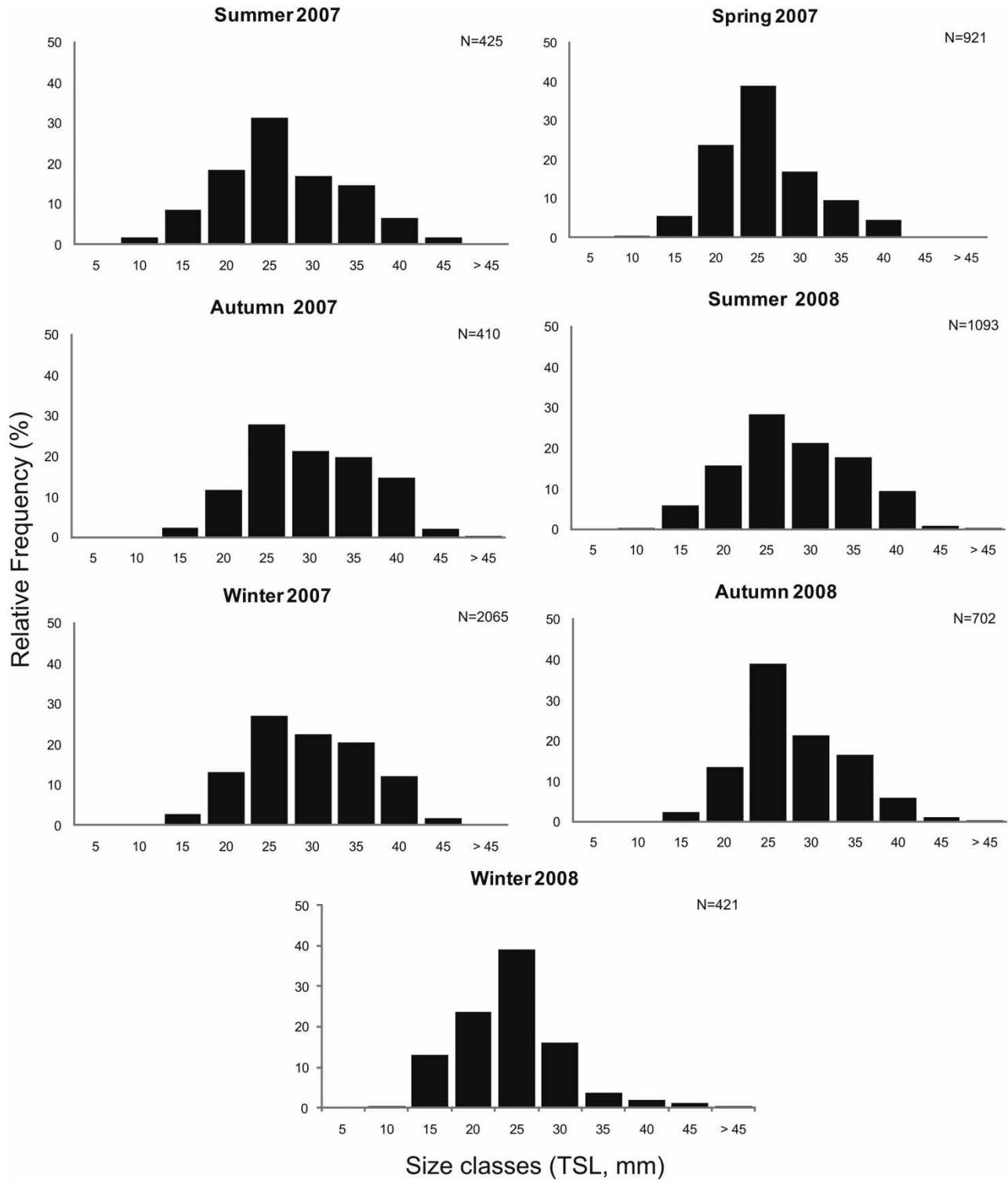


Figure 3. Seasonal frequency distributions of the total shell length (TSL) of *Buccinanops globulosus* during the study period.

February (austral summer) (NOAA-NASA: 16.86°C) (Figure 5B). Both temperature data sets were positively and significantly correlated ( $r = 0.77$ ,  $p < 0.05$ ,  $n = 9$ ). Minimum and maximum records of sea temperatures coincided with the highest percentages of dark and clear margins, respectively. The statistical relationship between SST and the percentage of dark

margin was inversely and marginally significant ( $r = -0.63$ ,  $p = 0.051$ ,  $n = 10$ ) (Figure 5C).

#### Growth model

Parameters obtained for VBGF for females, males, and both sexes combined are given in Table I.

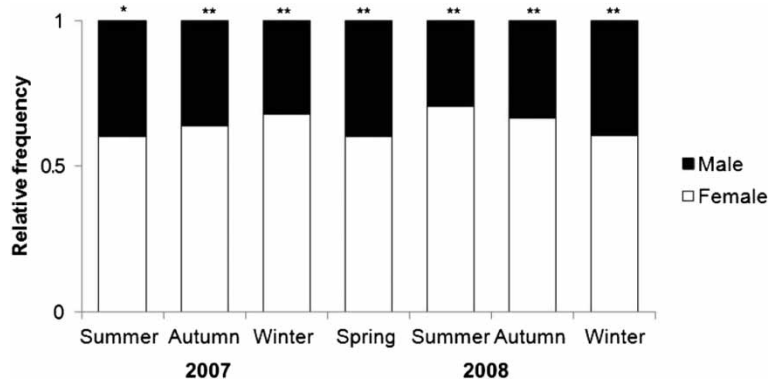


Figure 4. Sex ratio of *Buccinanops globulosus* from Bahía Nueva: \* and \*\* indicate significant and highly significant differences in the sex ratio, respectively.

Results of likelihood ratio tests showed that the overall VBGF and the asymptotic size significantly differed between sexes (VBGF,  $\chi^2$  test: 238.41

$df = 3$ ;  $TSL_{\infty}$   $\chi^2$  test: 102.55,  $df = 1$ ;  $p < 0.001$ , respectively). Females grow faster than males and asymptotic size was significantly higher than for

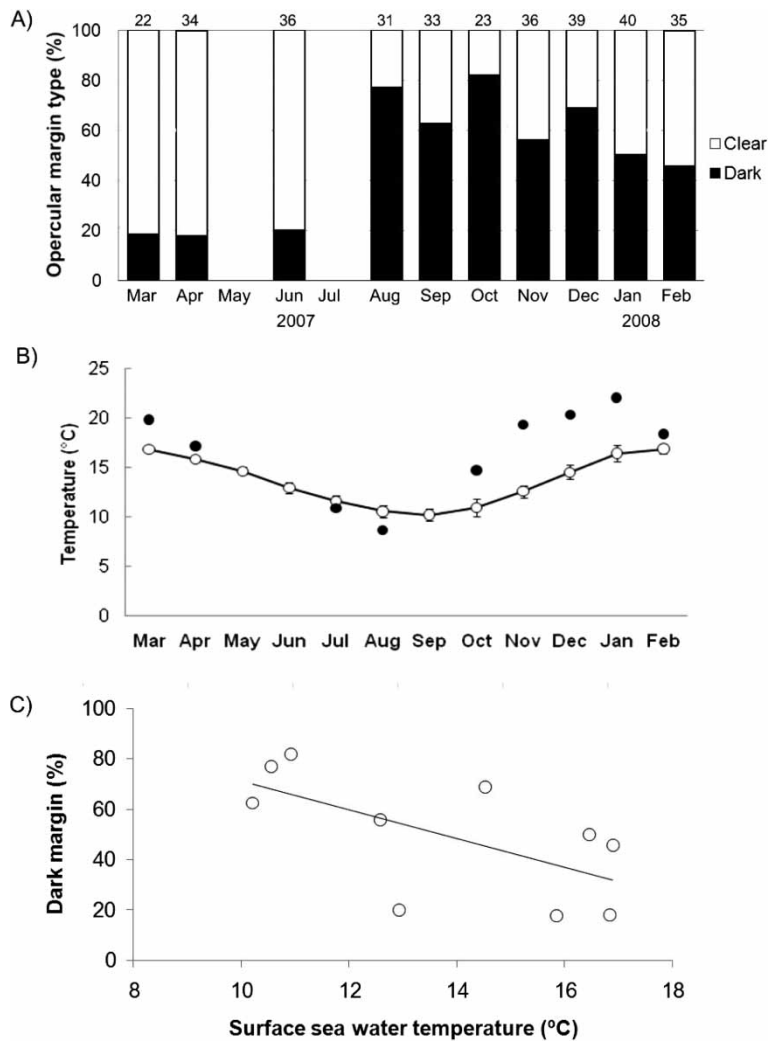


Figure 5. Seasonality of opercular margin pattern and its relationship with sea-surface temperature (SST). (A) Relative frequency (%) of clear and dark opercular margin, the number of opercula observed is presented above each column, there were no samples for May and July; (B) SST: data recorded in situ (solid circles, March 2007–February 2008) and mean ( $\pm$ SD) of NOAA-NASA data (open circles, period 1994–2007), and (C) relationship between SST and percentage of dark margin in opercula.

Table I. Growth parameters (VBGF) for *Buccinanops globulosus* females, males, and both sexes combined, estimated from operculum rings. Confidence intervals (95%) are shown between brackets.

	$TSL_{\infty}$ (mm)	$k$ (year <sup>-1</sup> )	$t_0$ (year)	$N$
Females	38.05 (36.83–39.73)	0.38 (0.33–0.43)	-0.43 (-0.58 to -0.30)	464
Males	27.09 (26.24–28.05)	0.73 (0.62–0.86)	-0.31 (-0.41 to -0.22)	257
All	37.96 (36.31–39.83)	0.33 (0.28–0.33)	-0.65 (-0.86 to -0.44)	678

males (Figure 6). Conversely,  $k$  did not differ significantly between sexes ( $\chi^2$  test,  $df=1$ ;  $p>0.05$ ).  $P$  index was slightly higher in females ( $P=4.32$ ) than in males ( $P=4.16$ ). Overall growth performance of *Buccinanops globulosus* is in the range of other nassariid species (Figure 7).

### Mortality

The instantaneous total mortality rate  $Z$  was estimated to be 0.34 year<sup>-1</sup> (95% confidence interval: 0.49–0.19 year<sup>-1</sup>) (Figure 8). The presence of the right descending arm in the catch curve and the value of  $r^2=0.97$  indicate that the single negative exponential model adequately fitted the data for whelks between three and seven years of age fitted the data.

### Discussion

*Buccinanops globulosus* individuals from Golfo Nuevo reach a maximum age of 8 years. This species has a potentially short lifespan compared with other species studied in the Argentine sea: *Zidona dufresnei*, *Adelomelon brasiliiana* (Lamarck, 1811), *Odontocymbiola magellanica* (Gmelin, 1791) and *Adelomelon beckii* which live between 17 and 29 years (Giménez et al. 2004; Cledón et al. 2005; Bigatti et al. 2007; Arrighetti et al. 2011), and within the range of the lifespan of several members

of the Nassariidae family (2–15 years; *Bullia rhodostoma* Reeve, 1847: McLachlan et al. 1979; *Nassarius reticulatus* Linnaeus, 1758: Tallmark 1980; Barroso et al. 2005; Chatzinikolaou & Richardson 2007, 2008; *Nassarius festivus* Powys, 1835: Morton & Chan 2004). Overall growth performance of *Buccinanops globulosus* ( $P=3.80$ – $4.82$ ) in North Patagonia is also in line with that of other nassariid species (*N. reticulatus*,  $P=3.73$ – $3.97$  based on data from Chatzinikolaou & Richardson 2007; *Bullia rhodostoma*,  $P=4.29$  based on data from McLachlan et al. 1979). Individuals from Bahía Nueva show an overall growth performance index intermediate between that of two other populations of this species, thus indicating site-specific growth differences (Table II). Also size distributions and sex ratio of Bahía Nueva population are different from those of other populations previously studied (Narvarte et al. 2008).

Evidence of the annual basis of ring formation is an integral component of any study of age and growth based on the use of hard structures such as the operculum to determine age. The high correlation obtained between operculum length (and width) and total shell length supports evidence that individual growth is accompanied by a deposition of material in opercula. Major deposition of material in the opercula of *B. globulosus* in Bahía Nueva occurred after sea water temperatures have reached the maximum values, thus indicating some delay

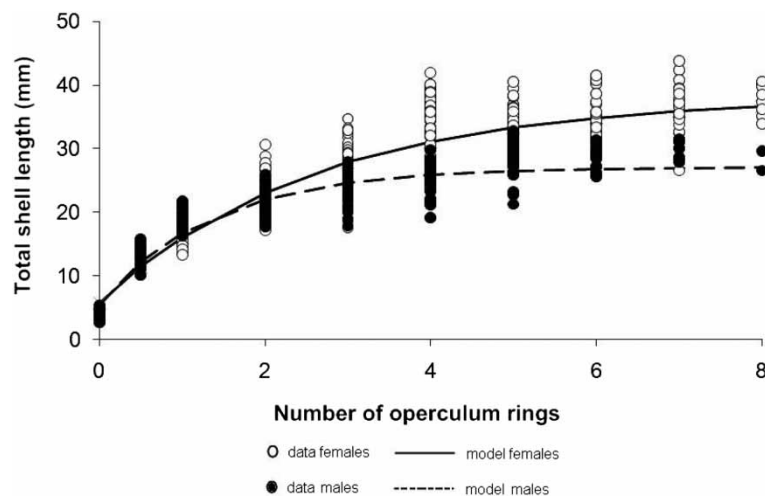


Figure 6. von Bertalanffy growth model fitted to length-at-age data from males and females of *Buccinanops globulosus*.



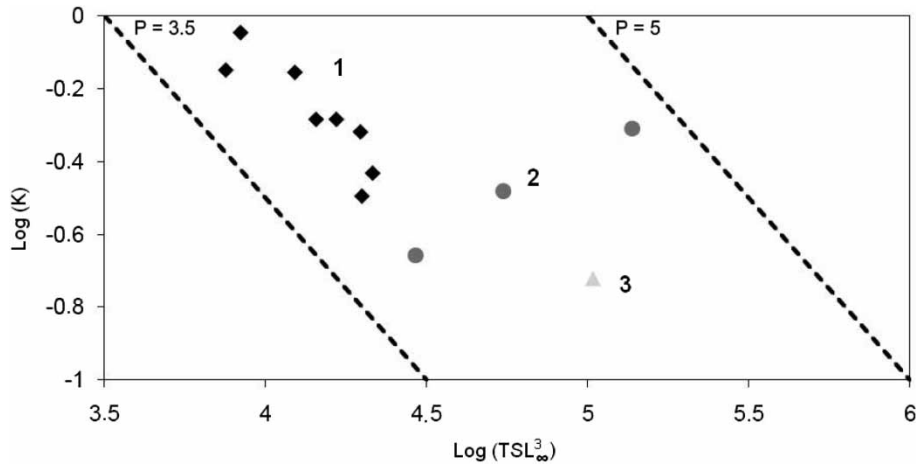


Figure 7. Auximetric grid for comparison the growth performance of *Buccinanops globulosus* and other nassariidae species. Growth performance index:  $P = \log(k * TSL_{\infty}^3)$ . 1. *Nassarius reticulatus* (Chatzinikolaou & Richardson 2007), 2. *Buccinanops globulosus* (Narvarte et al. 2008; this study), 3. *Bullia rhodostoma* (McLachlan et al. 1979).

between deposition and higher temperatures. On the contrary, observations performed in northern populations of *B. globulosus* showed maximum deposition as seawater temperature increases (Narvarte 2006; Narvarte et al. 2008). The delayed growth in relation to warm conditions and also the different timing of the period of cessation of growth between sites suggest that other factors may override the temperature effect, such as feeding activity and nutritional value of the food supply (Sebens 1987). Also, this delay may be related to the previous temperature that individuals had experienced at the different sites, with colder waters in Bahía Nueva than in populations from San Matías Gulf, such as has been described in other species, e.g. *N. reticulatus* (Chatzinikolaou & Richardson 2008). The combination of both sexes to determine the frequency of operculum margin, even when they differ in growth rates, may affect the results (Vasconcelos et al. 2012). Despite variability among all populations of all *B. globulosus* populations studied, an annual

pattern of deposition of material in the operculum is recognized at each site, thus allowing us to use operculum rings as a tool to determine age. Some methodological problems such as a high percentage of damaged opercula or the absence of clear rings, have been reported for this and other species (Kideys 1996; Richardson et al. 2005; Narvarte 2006), but in our study they were successfully overcome owing to the large abundance of the collected material.

The von Bertalanffy growth curve has been previously used for other populations of *B. globulosus* (Narvarte 2006; Narvarte et al. 2008) and in other species of nassariids, e.g. *B. rhodostoma* and *N. reticulatus* (McLachlan et al. 1979; Chatzinikolaou & Richardson 2007). In the present study, asymptotic length ranged from 36 to 40 mm, 8 years being the theoretical age at which the asymptotic shell length is achieved. Approximately 50% of the linear growth to  $TSL_{\infty}$  is attained within the first 2 years of the lifespan, and ca. 75% of the linear growth to  $TSL_{\infty}$  is attained within the first 4 years of the

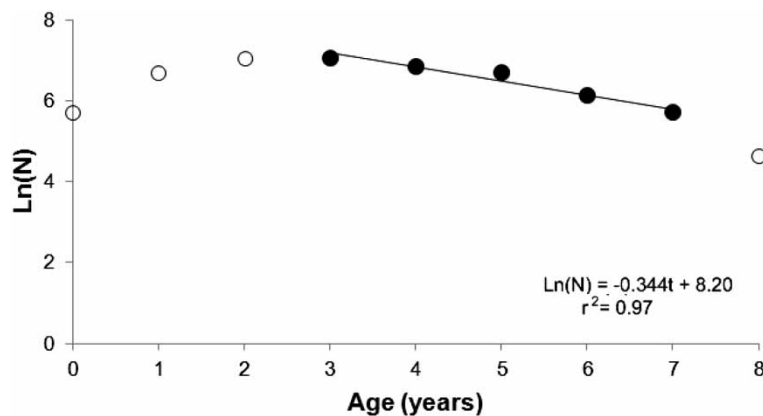


Figure 8. Catch curve of *Buccinanops globulosus* based on the size–frequency distribution and age-at-length key. Solid circles: data included in the regression; open circles: data excluded from the regression.

Table II. Population parameters of *Buccinanops globulosus* from different locations.  $TSL_{\infty}$ : asymptotic total shell length,  $k$ : catabolic coefficient.

Location	Size range	$TSL_{\infty}$ (mm)	$k$ (year <sup>-1</sup> )	Age range	Sex ratio	Source
Playa Villarino	4–61	51.60	0.49	0–7	♀ > ♂	Narvarte 2006; Narvarte et al. 2008
Bahía San Antonio	5–29	30.80	0.22	0–6	♀ < ♂	Narvarte et al. 2008
Bahía Nueva	5–47	37.96	0.33	0–8	♀ > ♂	This study

Note: Playa Villarino 40°45'S 64°30'W, Bahía San Antonio 40°45'S 64°56'W, Bahía Nueva 40°45'S 64°56'W.

lifespan. In other nassariid species it has also been observed that there is a faster growth during the first years of life. For example, *N. reticulatus* in Ria de Aveiro (Portugal) grew rapidly for the first 5 years, and then only a small increment in the shell was observed up to 11 years (Barroso et al. 2005).

Our results indicate that the overall growth performance of *B. globulosus* from Bahía Nueva was intermediate as compared with those previously estimated for other populations in northern Patagonia (Narvarte et al. 2008). Differences among populations seem to be related to the asymptotic length and to the parameter  $k$  and therefore to the potential maximal size that this species may reach. Indeed, size structure and maximum sizes of *B. globulosus* populations vary considerably along its geographical distribution. The size–frequency distribution of this species in the studied population was very different from those populations inhabiting Bahía de San Antonio (40°45'S 64°56'W) and Playa Villarino (40°45'S 64°30'W), in which maximum sizes are 31 and 62 mm, respectively (Narvarte et al. 2008). However, this variation is not related to latitude, thus suggesting that local conditions (e.g. food availability, predation pressure, exposure) are probably causing the variability observed as suggested in a previous study (Narvarte et al. 2008). Other explanations could involve variations in fishing pressure, with smaller individuals expected in heavily fished areas. However, this is unlikely because the site that is under fishing pressure (Playa Villarino) is the site with the largest individuals. Size variation among populations of marine gastropods, e.g. *Buccinum undatum* (Kideys 1996; Valentinsson et al. 1999; Shelmerdine et al. 2007), *B. rhodostoma* (McLachlan et al. 1979), *N. festivus* (Morton & Chan 2004), *N. reticulatus* (Chatzinikolaou & Richardson 2007, 2008), and *Haliotis rubra* (Leach, 1814) (Saunders et al. 2009a,b), is a common phenomenon and has been mainly ascribed to environmental factors.

Based on the existence of different morphological populations of *B. globulosus* and taking into account that the most common management strategy in gastropod fisheries is the use of a minimum size limit (MSL), we suggest that fisheries measures such as MSL for this species should be established

only for small geographical scales (Fahy et al. 2000; Morel & Bossy 2004; Shelmerdine et al. 2007; Eversole et al. 2008; Saunders et al. 2009b). It should be noted that the knowledge of the size at sexual maturity of both sexes at each fishing area is also needed for the establishment of MSL (Gendron 1992; Troynikov & Gorfine 1998).

Differences in the growth model between sexes were detected: females showed higher asymptotic length and a slightly higher overall growth performance index than males. This result is consistent with previous reports from two populations of *B. globulosus* (Narvarte et al. 2008). Body size is one of the most common differences between sexes in whelks, in general females being larger than males (Power & Keegan 2001; Ilano et al. 2004; Barroso et al. 2005; Eversole et al. 2008; Vasconcelos et al. 2008; Averbuj et al. 2010). The differences in growth rate between sexes may result from a different allocation of energy between reproductive and somatic activities at different ages (Stearns 1992). For example, females of *N. reticulatus* reared under laboratory conditions attained larger sizes than males although there were no differences in growth rate, thus indicating that females grow for a longer period during their lifespan (Chatzinikolaou & Richardson 2008). A large size in females is often related to higher fecundity, better parental care and male preferences for large females (Andersson 1994). However, if the species is being exploited, this large size may make females constitute the largest proportion of the catches. Also, if the sex ratio is female biased, as observed in this population (this study), then the harvest of females would be relatively common. As the mature females carry the egg capsules on the shell callus for long periods (2–4 months: Narvarte 2006; Averbuj & Penchaszadeh 2010), this implies not only a great loss of future fecundity but also of already deposited egg capsules. On the other hand, as the contribution of females to total recruitment may vary according to their size, selective extraction of large females may also endanger recruitment (e.g. Valentinsson 2002). Although the establishment of a maximum catchable length –e.g. the maximum length of males – may prevent overexploitation of the largest females, this measure would not be effective in practice.

The size structure showed seasonal and inter-annual differences mainly related to the relative proportion of each size class represented in the population, although the most common size class was 25 mm over the studied period. This variability could be explained in part by the sampling method used (bait to attract whelks) although natural processes such as recruitment and vertical migration cannot be ruled out. It is known that the same bait may present differential attractiveness to individuals according to their size, sex or physiological condition (Himmelman 1988; McQuinn et al. 1988; Lapointe & Sainte-Marie 1992; Arena et al. 1994; Gutiérrez et al. 2011; Westerberg & Westerberg 2011).

The instantaneous mortality rate  $Z$  estimated by this study for *B. globulosus* was approximately 0.34 per year, being the first report for the species. As no fishing activity has been developed and because recreational collection is sporadic (restricted mainly to the summer months),  $Z$  at Bahía Nueva may be considered equal to the instantaneous natural mortality rate  $M$ . Mortality is one of the most necessary parameters for stock assessment; however, it is also one of the most difficult parameters to obtain (Pauly 1980). Estimating mortality rates using catch curves requires that several assumptions be met, including constant recruitment and mortality over years, and equal catchability for all ages under consideration (Haddon 2001). The assumption of constant recruitment is likely to be violated for most species; however, moderate (and random) variations in recruitment will not affect the general form of a catch curve and mortality rates can still be estimated (Ricker 1975; Miranda & Bettoli 2007). On the other hand, extrapolating age from a subsample of individuals, as it occurs when using an age-at-length key, may have some bias and thus caution should be applied if estimates will be used for fishery management purposes (Bettoli & Miranda 2001). Despite this, the catch curve of *B. globulosus* suggests that the mortality rate across each fully recruited age class is relatively constant and, therefore, that the mortality rate estimated from the catch curve is fairly robust.

Gastropod fisheries are generally difficult to manage at sustainable levels because of their life history features, i.e. low growth rates, coupled with a late maturity, gregarious habits and in many cases, reduced dispersion, which make them prone to local extinctions and slow recovery after depletion (Gendron 1992; Valentinsson et al. 1999; Karpov et al. 2000; Eversole et al. 2008; Shalack et al. 2011). For *B. globulosus* there are no fishery policies and catches have been mainly regulated by its market price or by the availability of other more profitable resources to exploit (Narvarte 2006). Several management tools, such as the establishment of a

minimum size limit, season closures during the reproductive period, and the limitation of fishing effort, may be important for conservation of the species (e.g. Gendron 1992; Valentinsson et al. 1999; Fahy et al. 2000; Cudney-Bueno et al. 2008; Vasconcelos et al. 2008; Elahasni et al. 2010). The fact that populations under fishery pressure in both Patagonian gulfs are under different (independent) province administrations and policy controls may hamper the effectiveness of the use of different local minimum legal sizes as a fishery measure if it is not linked to the banning of catch transport among areas. Otherwise, undersized individuals from other areas may be fished and then sold where the minimum legal size is lower. Stocks from Bahía Nueva are in a 'pristine' level giving the opportunity to apply fishery measures without economic losses for stakeholders through experimental fishing programmes. This work provides basic information needed to develop fishery policies and can be used as a control baseline in case *B. globulosus* is exploited at this site.

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