Age and Growth of *Olivancillaria deshayesiana* (Gastropoda: Olividae) in the Southwestern Atlantic Ocean

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AGE AND GROWTH OF *OLIVANCILLARIA DESHAYESIANA* (GASTROPODA: OLIVIDAE) IN THE SOUTHWESTERN ATLANTIC OCEAN

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ABSTRACT

The population structure, particularly growth, age, mortality and somatic production of the olivid snail *Olivancillaria deshayesiana* were investigated. Annual formation of internal shell growth marks was confirmed by the record of stable oxygen isotopes in the shell, which reflects seasonal patterns of water temperature. A von Bertalanffy growth model fitted to 81 size-at-age data pairs, indicating that *O. deshayesiana* may attain 31 mm SL in about 10 years. The estimated total mortality Z and natural mortality M were 0.651 y^{-1} and 0.361 y^{-1}, respectively. Fishing mortality F was 0.290 y^{-1}, and the exploitation rate E was 0.445, indicating that this population was not overexploited at the time of the study. However, this situation may well change in the future, since the important prawn and shrimp fisheries (in intensity and scale) in the Mar del Plata area (38°20'S, 57°37'W) may indirectly affect the exploitation status of the studied population.

Key words: marine gastropod, age, growth, mortality, production.

INTRODUCTION

The determination of the individual age within a population is important for a comprehensive understanding of population dynamics and is required to establish growth and mortality patterns. Several methods have been used to study growth in gastropods (e.g., Shigemiya & Kato, 2001; Richardson et al., 2005a, b; Barroso et al., 2005), including the family Olividae (Stohler, 1969; Tursch et al., 1995; Rocha-Barreira, 2003; Caetano et al., 2003). In recent years, the technique by Epstein et al. (1953) based on the analysis of the isotope composition of calcium carbonate shells has been increasingly used by many authors (Giménez et al., 2004; Cledón et al., 2005; Bigatti et al., 2007; Arrighetti et al., 2010).

The family Olividae is composed of marine gastropods of moderate size, rarely exceeding 10 cm in total shell length. They inhabit sandy coastal shores in tropical and temperate regions of the world (Smith, 1998). There are eight *Olivancillaria* species in the southwestern Atlantic Ocean (Teso & Pastorino, 2011), some of which are the target of subsistence fisheries (Scelzo et al., 2002; Narvarte, 2006). This family, together with some volutids (i.e., *Adelomelon, Zidona*) and nassarids (i.e., *Buccinanops*) represent the most important endemic gastropods of sandy bottoms in the Argentine malacological province.

Olivancillaria deshayesiana is a small gastropod (up to 35 mm) distributed from Rio de Janeiro (22°59'S, 43°11'W), Brazil, to Necochea (38°33'S, 58°44'W), Argentina, at 0–60 m depth (Teso & Penchaszadeh, 2009; Teso & Pastorino, 2011). Individuals are semi-buried in the substratum, and their shell is partially covered by the mantle. The surface of the shell exhibits a distinct pattern of growth bands that have been used for ageing purposes, as in *O. auricularia* (Rocha-Barreira, 2003). In addition, Caetano et al. (2003) estimated growth and mortality of *O. vesica* from length-frequency data with computer-based methods.

Little is known about the reproduction and ecology of *O. deshayesiana*. Borzone (1995) described its embryonic development and egg capsules, and Teso & Penchaszadeh (2009) reported the imposex phenomenon in a population from the Mar del Plata area. This species

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is taken as bycatch in the fisheries for prawn *Artemesia longinaris* and shrimp *Pleoticus muelleri,* rather than being the direct target of artisanal fishermen (Scelzo et al., 2002). The objective of this study was to determine growth, mortality and the individual production of *O. deshayesiana* in the Mar del Plata area and to evaluate its significance for the local fishery.

MATERIALS AND METHODS

Specimens of *Olivancillaria deshayesiana* were collected monthly by bottom trawl (3 m mouth opening, 15 mm of mesh size) off Mar del Plata City (38°20'S, 57°37'W) between 5 and 12 m depth between October 2005 and September 2007. In this area, water temperature ranges between 8.4 and 20.8°C and salinity is rather constant at 33.8‰ (http://www.iafe.uba.ar/tele/Antares_argentina/; Guerrero & Piola, 1997). Animals were taken to the laboratory, where the shell was separated from the soft body. Shell length (SL) was measured with a vernier caliper to the nearest 1 mm and spiral growth trajectory length (SG) with a thread to the nearest 1 mm (Fig. 1). Shell-free wet mass (SFWM) was weighed to the nearest 0.1 g. The relationship between SL and SFWM was calculated.

Age and Growth

Only the pattern of internal growth marks was considered for the analysis due to the presence of columellar material forming a callus on the spire. The shells of ten individuals were cut along the whorls following the spiral growth trajectory from the apex to the posterior end of the aperture (Fig. 1), as described by Bigatti et al. (2007) and Arrighetti et al. (2010), among others. The cut surface was ground with sandpaper, using grits of P400, P1200, P2400 and P4000 grade. The polished shell cuts were examined by stereomicroscope. Visible internal growth marks were identified and the corresponding growth trajectory length SG_i from the apex to each mark *i* was measured as described by Cledón et al. (2005) and Gurney et al. (2005), among others. A stable oxygen isotope ratio ($\delta^{18}O$) was used to confirm the annual periodicity in the formation of growth marks. $\delta^{18}O$ in biogenic calcium carbonate structures is inversely proportional to temperature during carbonate deposition, as demonstrated empirically by Epstein & Lowenstam (1953) and Epstein et al. (1953).

Two representative specimens of 31 mm and 29 mm SL were used for stable isotope analysis. The carbonate samples (± 50 μg each) were collected from the central shell layer along the SG by means of a dental drill (bit size 0.5 mm)
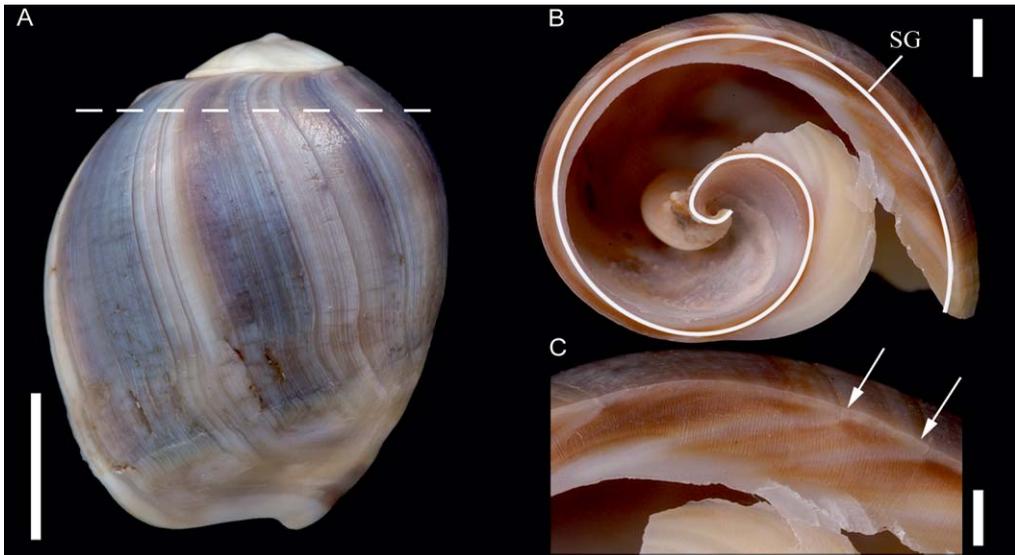

FIG. 1. *Olivancillaria deshayesiana*. FIG. 1A, B: Showing the spiral growth trajectory (SG), along which the samples for oxygen and carbon isotopes were taken, dash line in A indicates location of section in B; FIG. 1C: Detail of the internal growth marks (arrows). Scale bar = 1 cm.

at a sample-to-sample distance of about 1.5 mm. Stable oxygen isotope composition was determined in the stable isotope laboratory of the Alfred Wegener Institute with a Finnigan MAT251 mass spectrometer coupled to an automatic carbonate preparation device. The precision of measurements was better than ± 0.08‰ for $\delta^{18}O$ based on repeated analysis of a laboratory-working standard over a one-year period. Data are related to the Pee Dee belemnite (PDB) standard through repeated analyses of National Bureau of Standard (NBS) isotopic reference material 19 by:

$\delta = [(R_{sample} / R_{standard}) - 1] * 1000$

where R_{sample} and $R_{standard}$ are the isotopic relationship of the sample and of the standard, respectively. $\delta^{18}O$ ($d^{18}O_c$) values were converted into water temperature by the paleotemperature equation of Epstein et al. (1953), as modified by Craig (1965) and Anderson & Arthur (1983):

$T(°C) = 16.00 - 4.140 * (d^{18}O_c - d^{18}O_w) + 0.130 * (d^{18}O_c - d^{18}O_w)^2$

Sea water $\delta^{18}O$ ($d^{18}O_w$)) was estimated at -0.8‰ from the gridded data (version 1.1) of LeGrande & Schmidt (2006); see also the corresponding NASA website (http://data.giss. nasa.gov/o18data). Visual shell marks coinciding with $\delta^{18}O$ peaks were interpreted as winter growth marks, and the distance between two subsequent winter growth marks as the annual shell increment. Thus, each winter growth mark i and its corresponding shell growth trajectory length SG_i were interpreted as one size-at-age data pair. SG_i was translated into shell length SL_i by means of the linear relationship between the two parameters. The iterative non-linear Newton algorithm was used to fit a growth model to the size-at-age data. The specialized von Bertalanffy growth model was found to fit the data best:

$SL_t = SL_\infty * (1 - e^{-k*(t-to)})$

where SL_∞ is asymptotic shell length, K is the body growth coefficient, t is age and t_0 is a theoretical age at which length equals zero. Overall growth performance was estimated by the index:

$P = \log(K * SL_\infty^3)$

as described by Moreau et al. (1986) & Pauly et al. (1994).

Production

Individual somatic production was calculated by the mass-specific growth rate method ac-

cording to Brey (2001) from the size frequency distribution, the size-body function and the growth model parameters:

$P_j = BM_j * G_j$

where BM_j is the mean individual body mass at size j and Gj is the annual mass specific growth rate at size j as calculated by:

$G_j = b * K * (SL_\infty / SL_j - 1)$

Smaller size classes are likely to be undersampled due to the selectivity of the commercial bottom trawl, and thus population production (P) was not calculated.

Mortality, Yield per Recruit and Exploitation Rate

It was presumed that mortality in *O. deshayesiana* is adequately described by the single negative exponential mortality model and the corresponding size-converted catch curve (Pauly, 1984a, b) was used to estimate total mortality rate Z (y-1),

$N_j/\Delta t_j = N_0 * e^{-Z ti}$

where N_j is number in size class j, Δt_j is time required to grow through size class j, and t_J is age at midsize of size class j. Natural mortality rate M was estimated by means of an empirical model that relates production-to-biomass ratio (P/B) ratio to maximum age t_{max} (y), maximum body mass BM_{max} (kJ) and mean water temperature T (Kelvin) in unexploited benthic populations (Brey, 1999, 2001). If growth can be described by the von Bertalanffy model and mortality by the single negative exponential model, mortality rate M and P/B ratio are equivalent (Allen, 1971), hence:

$\log(M) = 1.672 + 0.993 * \log(1/t_{max}) - 0.035 * \log(BM_{max}) - 300.447/T$

$N = 901$, $r^2 = 0.880$

Maximum age and body mass were inferred from the largest animal through the growth model and the size-mass relationship (applying the conversion factor 3.818 kJ/gWM, average for Gastropoda, Brey, 2001).

Fishing mortality F and exploitation rate E were computed by:

F = Z – M, and E = F/Z

A selection curve giving the probability of capture PC_j per size class j was computed by a procedure outlined by Pauly (1984a, b). Yield per recruitment was computed by the Beverton & Holt (1964) model, from which a predicted value for optimum exploitation rate was also obtained.
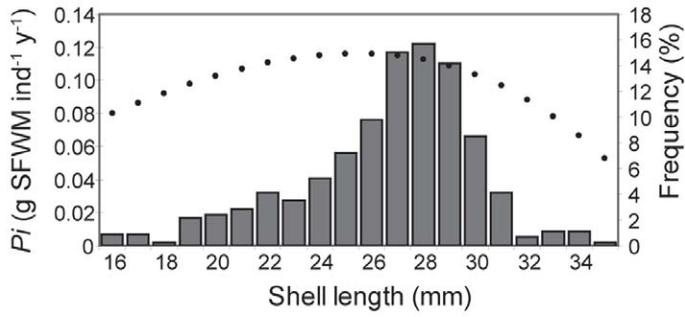
FIG. 2. Size-frequency distribution of *Olivancillaria deshayesiana* (N = 420) from Mar del Plata area in 2005–2007. Superimposed dotted line indicates individual somatic production *Pi* (g shell-free wet mass year-1) per size class.
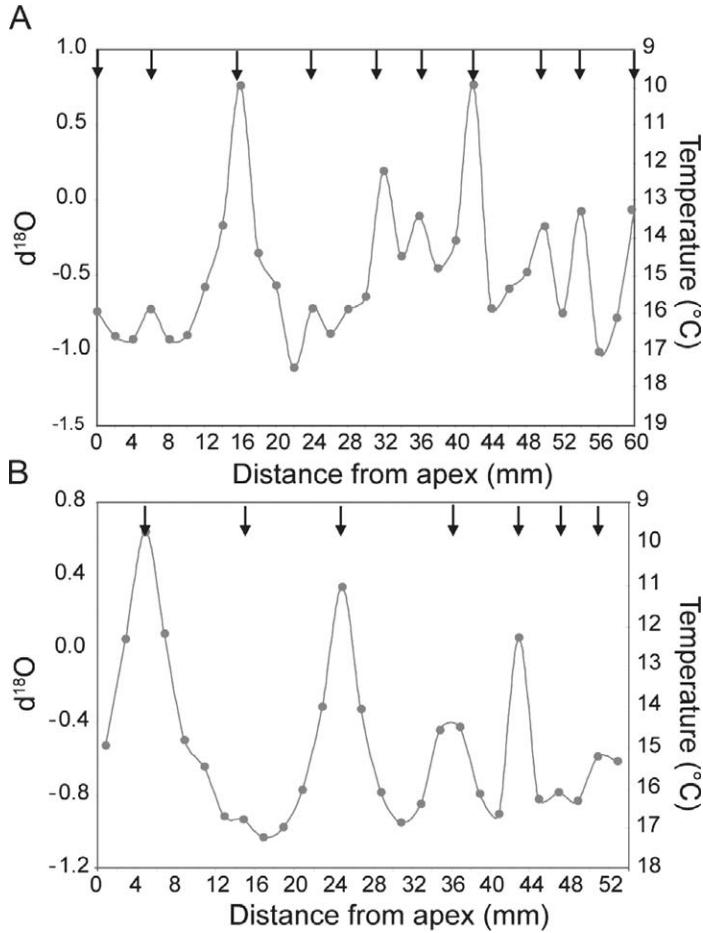

FIG. 3. δ18O profile along a transect from apex to shell edge from two individuals of *Olivancillaria deshayesiana*. FIG. 3A: 31 mm SL, 10 y; FIG. 3B: 29 mm SL, 7 y. Arrows indicate position of internal growth marks. Water temperature (right-hand scale) computed from carbonate 18O by the paleotemperature equation of Epstein et al. (1953); see text for details.
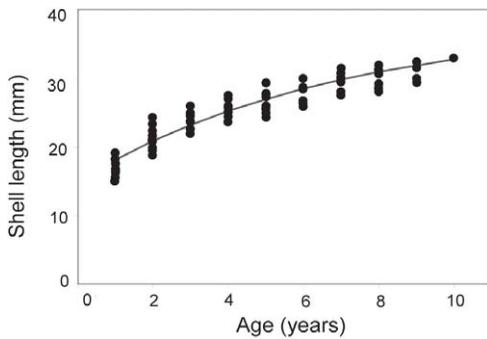
FIG. 4. Von Bertalanffy growth curve for *Olivancillaria deshayesiana* $SL_t = 38 * (1 − e^{-0.147*(t-3.392)})$; $r^2 = 0.913$; $N = 81$ size-at-age data pairs obtained from the 10 specimens analyzed.

RESULTS

A total of 470 snails were collected, which ranged from 16 to 35 mm in total shell length (Fig. 2). Shell-free wet body mass ranged from 0.4 to 10.8 g and was related to *SL* by:

$\log(SFWM) = -4.76 + 3.60 * \log(SL)$; (g – mm; $r^2 = 0.77$; $N = 470$)

SL was linearly related to *SG,* the distance from the apex along the growth trajectory to the aperture of the shell, by:

$SL = -42.87 + 3.54 * SG$; (mm – mm; $r^2 = 0.93$; $N = 30$)

Age and Growth

The $\delta^{18}O$ profiles showed distinctly oscillating pattern in both shells (Fig. 3). The average
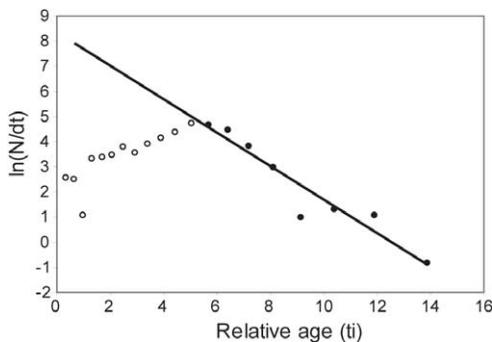

FIG. 5. Size-converted catch curve based on the size-frequency distribution (Fig. 2) and growth function (Fig. 4) of *Olivancillaria deshayesiana*. Dots: data included in regression; circles: data excluded from regression. $\ln(N/dt) = -0.651\ ti + 8.193$; $r^2 = 0.93$; 95% confidence range of slope = ± 0.164.

range of -1.1‰ to + 0.8‰ $\delta^{18}O$ corresponded to a temperature range of about 9.8°C to 17.4°C. Almost all $\delta^{18}O$ maxima (corresponding to temperature minima) coincided with a shell growth mark, thereby indicating that one growth mark is formed each winter.

The von Bertalanffy growth model:

$SL_t = 38 * (1 − e^{-0.147*(t-3.392)})$; $N = 81$, $r^2 = 0.913$

fitted best the 81 size-at-age data pairs obtained from the 10 specimens analyzed (Fig. 4). Overall growth performance of *O. deshayesiana* was $P = 3.91$.

Production

Individual somatic production P_j increased with size j up to a maximum of 0.116 g SFWM year^{-1} at 25 mm SL and decreased towards larger sizes (Fig. 2).

Mortality, Yield per Recruit and Exploitation Rate

Total mortality rate Z of *O. deshayesiana* amounted to 0.651 y^{-1} (95% confidence range ± 0.164, Fig. 5). Natural mortality rate M was estimated at 0.361 y^{-1}, with $t_{max} = 20.7$ y (at 35 mm SL), $BM_{max} = 41.23$ kJ (10.8g SFWM) and $T = 286$ K. Accordingly, fishing mortality F amounted to 0.290 y^{-1} and exploitation rate E to 0.445. Figure 6A shows the selection curve for the currently applied sampling technique. Specimens less than 17 mm were not caught at all; probability of capture attained 50% at 22.8 mm *SL* and 100% ≥ 27 mm *SL*. The optimum exploitation rate was estimated at 0.770 (Fig. 6B).

DISCUSSION

Stable Oxygen Isotope Ratios and Environmental Temperature

In the shell of *O. deshayesiana*, stable oxygen isotope ratios reflect seasonal patterns of water temperature; each maximum $\delta^{18}O$ value corresponds to a winter minimum temperature. Thus, the distinct shell mark at each $\delta^{18}O$ maximum indicates a slowing shell growth during winter, as observed for other gastropods from the Mar del Plata region (Cledón et al., 2005; Giménez et al., 2004). The average annual temperature inferred from the $\delta^{18}O$ profile in the shell ranged between 9.8°C and 17.4°C, in agreement with the reported seasonal instrumental temperatures of 8.4–20.8°C in the same area (http://www.iafe.uba.ar/tele/Antares_argentina/).
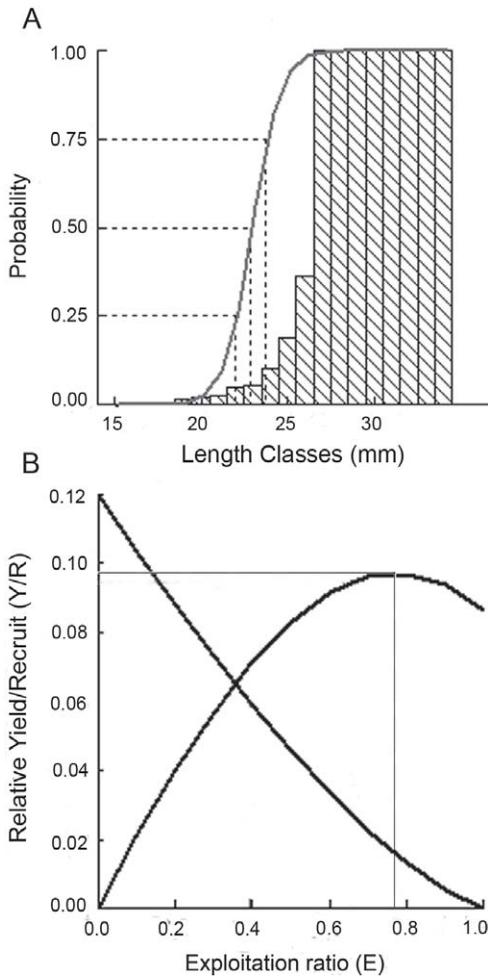
A

B

FIG. 6. *Olivancillaria deshayesiana*. FIG. 6A: Plot of probability of capture versus length in *Olivancillaria deshayesiana*; FIG. 6B: Yield per recruitment in *Olivancillaria deshayesiana* based on the Beverton and Holt (1964) model (calculations by means of the FISAT software reference).

Age and Growth

From the isotopic data and the internal growth marks, it is inferred that *O. deshayesiana* may reach 31 mm SL in about 10 years. This maximum age is similar to those reported for *Olivella biplicata* (8–12 years) from California, USA (Stohler, 1969) and *Oliva oliva* (10 years) from Papua, New Guinea (Tursch et al., 1995), while it is distinctly above those estimated for *O. auricularia* (6 years) from Rio Grande, Brazil (Rocha-Barreira, 2003) and *O. vesica* (4–5 years) from Rio de Janeiro, Brazil (Caetano

et al., 2003). In general, cold-water marine invertebrates found at higher latitudes grow more slowly and live longer than closely related species occurring in warmer waters (Dehnel, 1955; Ray, 1960; Fonseca et al., 2000). This may account for the shorter life span of *O. vesica* compared with species of the same genus living at higher latitudes.

The specialized von Bertalanffy model describes the shell growth of *O. deshayesiana* properly, because it is a gastropod in which shell growth has no inflexion point (e.g., Frank, 1965; Caetano et al., 2003; Ilano et al., 2004; Richardson et al., 2005a; Chatzinikolaou & Richardson, 2008; Eversole et al., 2008; Arrighetti et al., 2011). This is in contrast to other gastropods with a sigmoid pattern of shell growth (e.g., Giménez et al., 2004; Cledón et al., 2005; Bigatti et al., 2007). Therefore, all standard fishery analysis based on the von Bertalanffy model, such as virtual population analysis, applies to *O. deshayesiana*.

The overall growth performance of *O. deshayesiana* (P = 3.91) is below the range found for other large commercially important gastropod species from temperate regions (reviewed in Arrighetti et al., 2011).

Production, Mortality and Exploitation Rate

The size-frequency distribution was based on data from catches with nets of 15 mm mesh size, and therefore sampling efficiency was lower than 50% for individuals smaller than 23 mm SL (Fig. 6A). This is clearly seen in the size-converted catch curve, where individuals younger than 5 years (27 mm SL) are underrepresented.

Therefore, estimates of production and productivity based on this distribution would distinctly underestimate true population values. The estimated fishing mortality of 0.290 y^{-1} and the current exploitation rate of 0.445 indicate that this population was not overexploited at the time of the study. However, this situation may well change in the future, since the important prawn and shrimp fisheries (in intensity and scale) in the Mar del Plata area (Scelzo et al., 2002) may indirectly affect the exploitation status of the studied population. Furthermore, *O. deshayesiana* is a food source for commercial fishes such as *Urophycis brasiliensis* (Brazilian codling), *Sympterigia bonapartei* (ray), *Callorynchus callorynchus* (elephant fish) and *Micropogonias furnieri* (white croaker) (Penchaszadeh et al., 2006). It is possible that the depletion of the population may cause a shift to a new stable trophic situation.

LITERATURE CITED

ALLEN, K. R., 1971, Relation between production and biomass. *Canadian Journal of Fisheries and Aquatic Science*, 28: 1537–1581.

ANDERSON, T. F. & M. A. ARTHUR, 1983, Stable isotopes of oxygen and carbon and their application to sedimentologic and paleoenvironmental problems. *Stable Isotopes in Sedimentary Geology, SEPM Short Course*, 10: 111–155.

ARRIGHETTI, F., T. BREY, A. MACKENSEN & P. E. PENCHASZADEH, 2011, Age, growth and mortality in the giant snail *Adelomelon beckii* (Broderip 1836) on the Argentinean shelf. *Journal of Sea Research*, 65: 219–223.

BARROSO, C. M., M. NUNES, C. A. RICHARDSON & M. H. MOREIRA, 2005, The gastropod statolith: a tool for determining the age of *Nassarius reticulatus*. *Marine Biology*, 146: 1139–1144.

BEVERTON, R. J. H. & S. J. HOLT, 1964, Manual of methods for fish stock assessment. Part 2. Tables of yield functions. *FAO Fisheries Technical Paper*, 38: 1–67.

BIGATTI, G., P. E. PENCHASZADEH & M. CLEDÓN, 2007, Age and growth in *Odontocymbiola magellanica* (Gastropoda: Volutidae) from Golfo Nuevo, Patagonia, Argentina. *Marine Biology*, 150: 1199–1204.

BORZONE, C. A., 1995, Ovicápsulas de Prosobranquios (Mollusca: Gastropoda) de una playa arenosa expuesta del sur del Brasil. *Iheringia, Serie Zoologia*, 79: 47–58.

BREY, T., 1999, Growth performance and mortality in aquatic benthic invertebrates. *Advances in Marine Biology*, 35: 153–223.

BREY, T., 2001, *Population dynamics in benthic invertebrates*. A virtual handbook. Version 01.2.Available on http://www.thomas-brey.de/science/virtualhandbook.

CAETANO, C. H. S., V. G. VELOSO & R. S. CARDOSO, 2003, Population biology and secondary production of *Olivancillaria vesica vesica* (Gmelin, 1791) (Gastropoda: Olividae) on a sandy beach in southeastern Brazil. *Journal of Molluscan Studies*, 69: 67–73.

CHATZINIKOLAOU, E. & C. A. RICHARDSON, 2008, Population dynamics and growth of *Nassarius reticulatus* (Gastropoda: Nassariidae) in Rhosneigr (Anglesey, UK). *Marine Biology*, 153: 605–619.

CLEDÓN, M., T. BREY, P. E. PENCHASZADEH & W. ARNTZ, 2005, Individual growth and somatic production in *Adelomelon brasiliana* (Gastropoda; Volutidae) off Argentina. *Marine Biology*, 147: 447–452.

CRAIG, H., 1965, The measurement of oxygen isotope paleotemperatures. Pp. 161–182, in: E. TONGIORGI, ed., *2nd conference on stable isotopes in oceanographic studies and paleotemperatures*. Consiglio Nazionalle Delle Ricerche, Speleto, Italy, 130 pp.

DEHNEL, P. A., 1955, Rates of growth of gastropods as a function of latitude. *Physiological Zoology*, 28: 115–144.

EPSTEIN, S. & H. A. LOWENSTAM, 1953, Temperature shell-growth relation of recent and interglacial Pleistocene shoal-water biota from Bermuda. *Geological Society of America Bulletin*, 61: 424–438.

EPSTEIN S., R. BUCHSBAUM, H. A. LOWENSTAM & H. C. UREY, 1953, Revised carbonate-water isotopic temperature scale. *Geological Society of America Bulletin*, 64: 1315–1326.

EVERSOLE, A. G., W. D. ANDERSON & J. J. ISELY, 2008, Age and growth of the knobbed whelk *Busycon carica* (Gmelin 1791) in South Carolina subtidal waters. *Journal of Shellfish Research*, 27: 423–426.

FONSECA, D. B., V. G. VELOSO & R. S. ARDOSO, 2000, Growth, mortality and reproduction of *Excirolana braziliensis* Richardson, 1912 (Isopoda: Cirolanidae) on the Prainha beach, Rio de Janeiro, Brazil. *Crustaceana*, 73: 535–545.

FRANK, P. W., 1965, Shell growth in a natural population of the turban snail, *Tegula funebralis*. *Growth*, 29: 395–403.

GIMÉNEZ, J., T. BREY, A. MACKENSEN & P. E. PENCHASZADEH, 2004, Age, growth and mortality of the prosobranch snail *Zidona dufresnei* (Donovan, 1823) in the Mar del Plata area, SW Atlantic Ocean. *Marine Biology*, 145: 707–712.

GUERRERO, R. A. & A. R. PIOLA, 1997, Masas de agua en la plataforma continental. Pp. 107–118, in: E. E. BOSCHI, ed., *El mar y sus recursos pesqueros*. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata.

GURNEY, L. J., C. MUNDY & M. C. PORTEUS, 2005, Determining age and growth of abalone using stable oxygen isotopes: a tool for fisheries management. *Fisheries Research*, 72: 353–360.

ILANO, A. S., K. FUJINAGA & S. J. NAKAO, 2004, Reproductive cycle and size at sexual maturity of the commercial whelk *Buccinum isaotakii* in Funka Bay, Hokkaido, Japan. *Journal of the Marine Biological Association of the United Kingdom*, 83: 1287–1294.

LEGRANDE, A. N. & G. A. SCHMIDT, 2006, Global gridded data set of the oxygen isotopic composition in seawater. *Geophysical Research Letters*, 33: L12604.

MOREAU, J., C. BAMBINO & D. PAULY, 1986, A comparison of four indices of overall fish growth performance based on 100 tilapia populations (Fam. Cichlidae). Pp. 201–206, in: J. L. MACLEAN, L. B. DIZON & L. V. HOSILLOS, eds., *The first Asian fisheries forum*. Asian Fisheries Society, Manila, Philippines, 727 pp.

NARVARTE, M. A., 2006, Biology and fishery of the whelk *Buccinanops globulosum* (Kiener, 1834) in northern coastal waters of the San Matías Gulf (Patagonia, Argentina). *Fisheries Research*, 77: 131–137.

PAULY, D., 1984a, Length-converted catch curves: a powerful tool for fisheries in the tropics (part II). *Fishbyte*, 2: 17–19.

PAULY, D., 1984b, Length-converted catch curves: a powerful tool for fisheries in the tropics (part III). *Fishbyte*, 2: 8–10.

PAULY, D., J. MOREAU & F. GAYANILO, 1994, A new method for comparing the growth performance of fishes, applied to wild and farmed Tilapias. Pp. 1–41, in: R. S. V. PULLIN, J. LAZARD, M. LEGENDRE, J. B. AMON KOTHIAS & D. PAULY, eds., *The third international symposium on Tilapia in aquaculture*. ICLARM Conference Proceedings.

RAY, C., 1960, The application of Bergmann's and Allen's rules to the poikilotherms. *Journal of Morphology*, 106: 85–108.

RICHARDSON, C. A., P. R. KINGSLEY-SMITH, R. SEED & E. CHATZINIKOLAOU, 2005a, Age and growth of the naticid gastropod *Polinices pulchellus* (Gastropoda: Naticidae) based on length frequency analysis and statolith growth rings. *Marine Biology*, 148: 319–326.

RICHARDSON, C. A., C. SAUREL, C. M. BARROSO & J. THAIN, 2005b, Evaluation of the age of the red whelk *Neptunea antiqua* using statoliths, opercula and element ratios in the shell. *Journal of Experimental Marine Biology and Ecology*, 1: 55–64.

RIOS, E. C., 2009, *Compendium of Brazilian sea shells*. Editora da Fundaçao Universidade do Rio Grande, 668 pp.

ROCHA-BARREIRA, C. A., 2003, Determinaçao da idade de *Olivancillaria vesica auricularia* (Lamarck, 1810) (Mollusca: Gastropoda: Olividae) na praia do Cassino, Rio Grande, Rio Grande do Sul, Brasil. *Arquivos de Ciencia do Mar*, 3: 29–35.

SCELZO, M. A., J. MARTINEZ ARCA & N. M. LUCERO, 2002, Diversidad, densidad y biomasa de la macrofauna componente de los fondos de pesca "camarón-langostino", frente a Mar del Plata, Argentina (1998–1999). *Revista de Investigación y Desarrollo Pesquero*, 15: 43–65.

SHIGEMIYA, Y. & M. KATO, 2001, Age distribution, growth, and lifetime copulation frequency of a freshwater snail, *Clithon retropictus* (Neritidae). *Population Ecology*, 43: 133–140.

SMITH, B. J., 1998, Superfamily Muricoidea. Pp. 819–845, in: P. L. BEESLEY, G. J. B. ROSS & A. WELLS, eds., *Mollusca: The Southern Synthesis. Fauna of Australia*, *Vol. 5, part B.* CSIRO publishing, Melbourne, A: viii + pp. 565–1234.

STOHLER, R., 1969, Growth study in *Olivella biplicata* (Sowerby, 1825). *The Veliger*, 11: 259–267.

TESO, V. & G. PASTORINO, 2011, A revision of the genus Olivancillaria (Mollusca: Olividae) from the southwestern Atlantic. *Zootaxa*, 2889: 1–34.

TESO, V. & P. E. PENCHASZADEH, 2009, Beach filling and imposex in *Olivancillaria deshayesiana* (Mollusca: Gastropoda: Olividae) from the coast of Mar del Plata, Argentina *Journal of the Marine Biological Association of the United Kingdom*, 89: 557–562.

TURSCH, B., J. M. OUIN & J. BOUILLON, 1995, On the structure of a population of *Oliva oliva* (L., 1758) in Papua New Guinea (Studies on Olividae. 22). *Apex*, 10: 29–38.