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Growth and production of the venerid bivalve *Eurhomalea exalbida* in the Beagle Channel, Tierra del Fuego

Betina J. Lomovasky^{a,*}, Thomas Brey^b, Elba Morriconi^a, Jorge Calvo^a

^aCentro Austral de Investigaciones Científicas (CADIC- CONICET) C.C. 92 (V9410BFD) Ushuaia, Tierra del Fuego, Argentina

^bAlfred Wegener Institute for Polar and Marine Research, P.O. Box 120161, 27515 Bremerhaven, Germany

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Abstract

Growth, mortality and productivity of the hard clam *Eurhomalea exalbida* from Ushuaia Bay, Beagle Channel, were investigated. The parameters of the von Bertalanffy growth function were estimated to be $H_{\infty} = 74$ mm, $K = 0.18$ y^{-1} , $t_0 = 0.15$ y. Maximum individual production amounted to 2.74 g shell-free wet mass (SFWM) at 49.5 mm shell height. Animals between 40 mm and 70 mm shell height contributed most to overall population somatic production P of 134 g SFWM m^{-2} y^{-1} . Mean annual biomass B amounted to 1123 g SFWM m^{-2} y^{-1} . Annual P/B ratio and mortality rate Z were estimated to be 0.12 y^{-1} and 0.14 y^{-1} , respectively. Slow growth and low turnover make this population less suitable for sustainable commercial exploitation.

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1. Introduction

The venerid *Eurhomalea exalbida* (Chemnitz, 1795) is a littoral species distributed throughout coastal southern South America, from the Beagle Channel (54° 50' S) to the island of Chiloe (42° S) on the Pacific coast (Soot-Ryen, 1959; Dell, 1964; Osorio et al., 1979) and to the province of Buenos Aires (36° S) on the Atlantic coast (Carcelles, 1944, 1950).

E. exalbida is commercially exploited in various regions along the Pacific coast of South America (Osorio et al., 1979). No records of commercial exploitation exist from the Atlantic side, but Ciocco

(1995) assume that *E. exalbida* may be bycatch of the fishery on *Ameginomya antiqua*, another venerid, in San José Golf (42°20' S, 64°30' W).

Few studies on *E. exalbida* exist. In Chile, population dynamics have been investigated by Urban and Tesch (1996). Schuldt (1975) studied the reproduction at Punta Loma, Chubut, Argentina (42°47' S). Currently the population from Ushuaia Bay, Beagle Channel, is being investigated in more detail: energy transfer (Lomovasky et al., 2001), reproduction (Morriconi et al., 2002), age-pigment (lipofuscin) formation (Lomovasky et al., 2002) and long-term oscillations in shell growth (Lomovasky et al., unpubl. ms) are being analysed.

In the Beagle Channel, *E. exalbida* encounters the lowest temperatures throughout its geographic distribution with average monthly maximum and minimum

* Corresponding author.

E-mail address: betinal@hotmail.com (B.J. Lomovasky).

temperatures of 8.7 °C and 4.5 °C, respectively (Schroeder, unpubl. data). As low temperature slows down oogenesis as well as growth in bivalve molluscs (Giese, 1959; Sastry, 1979; Pearse et al., 1991), it limits population turnover and hence the capacity of the population to withstand commercial extraction. Consequently, careful studies of potentially exploitable populations are the more important in high latitudes in order to prevent rapid overexploitation. The objective of this study is to determine growth, mortality and productivity of an *E. exalbida* population in the Beagle Channel.

2. Material and methods

2.1. Sampling

A population of the hard clams *Eurhomalea exalbida* (Chemnitz, 1795) was studied in the Beagle Channel (Fig. 1): One site in Ushuaia Bay (54°50' 18" S, 68°16' 25" W) was sampled monthly between October 1998 and September 1999. At each date five sediment cores of 50 × 50 cm surface area and 20 cm depth were dug out at randomly selected positions by SCUBA divers in 3 to 5 m water depth and sieved through 5 mm mesh size. We checked the presence of specimens <= 5 mm shell height by analysing the unsieved content of two additionally taken 25 × 25 cm cores at each sampling date. During the study period salinity ranged between 30.9 ppm and 32.9 ppm, and monthly mean seawater

temperature ranged between 8.7 °C in summer and 4.5 °C in winter (Schroeder, unpubl. data).

In all individuals collected we measured shell height (H, umbo to the ventral margin), shell length (L, anterior-posterior axis) and shell width (W) with a precision of ± 0.1 mm. We also determined total mass (TM), shell mass (SM) as well as shell-free wet mass (SFWM) with a precision of ± 0.01 g.

2.2. Growth

Individual age was inferred from shell growth bands of 214 specimens. Each right valve was embedded in epoxy resin and sectioned along the axis of maximum growth in height (H). The cross-sections were polished on lapidary wheels using grits of 120, 400, 600 and 1000 grade. Polished shell cuts were examined by stereo microscope using reflecting light. Acetate peels were made of polished and etched sections to confirm the pattern found (Rhoads and Lutz, 1980).

Stable oxygen isotope ratios ($\delta^{18}\text{O}$) can be used to confirm seasonality of growth in calcareous species (see Forester et al., 1973; Krantz et al., 1987; Wefer and Berger, 1991). Following previous attempts by Jones et al. (1983), Krantz et al. (1984), Donner and Nord (1986), Brey and Mackensen (1997) and others, we used $\delta^{18}\text{O}$ in the shell to test whether growth rings are formed annually in *E. exalbida*. For isotope analysis, we drilled carbonate samples of about 50 µg each from the outer shell layer of three individuals in an equally spaced dorsal-to-ventral series using a small dental drill (bit size 0.5 mm). Oxygen isotopes of these samples were measured with a Finnigan MAT251 mass spectrometer coupled to an automatic carbonate preparation device. The precision of measurements is better than ± 0.08 ‰ for $\delta^{18}\text{O}$, based on routine measurements of a laboratory working standard. Data are related to the Pee Dee belemnite (PDB) standard through repeated analyses of National Bureau of Standard (NBS) isotopic reference material 19 (Hut, 1987).

The von Bertalanffy growth model was fitted to the shell height-at-age data using the non-linear iterative Newton algorithm.

$$H_t = H_\infty (1 - e^{-k(t-t_0)}) \quad [\text{mm}, y] \quad (1)$$

where H_∞ is the asymptotic height, K is the growth constant, t the age and t_0 the age at zero height.

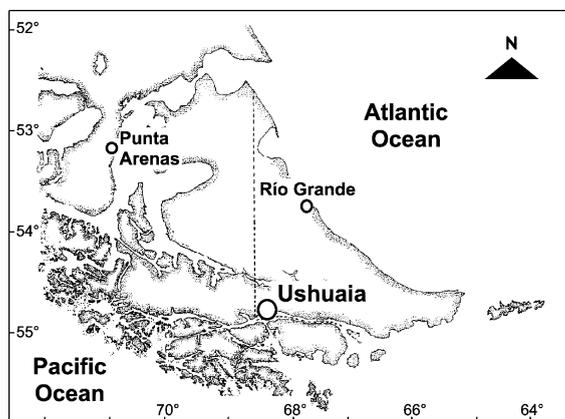


Fig. 1. Sampling site in the Beagle Channel, South America.

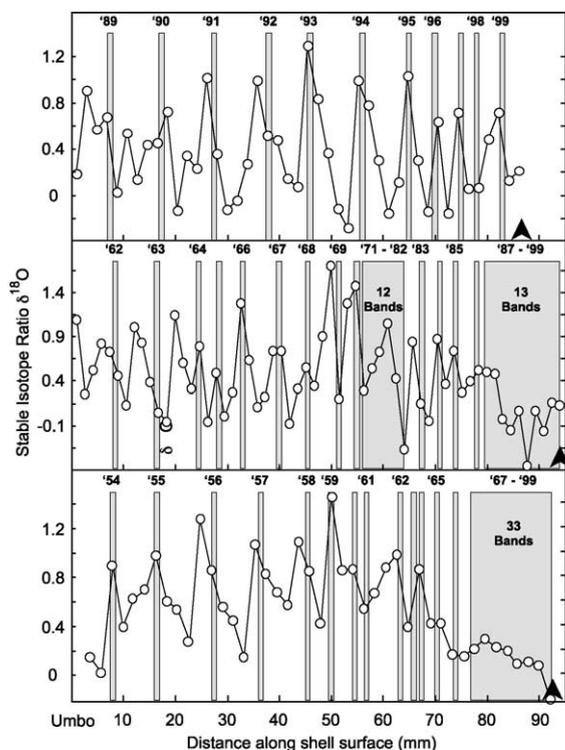


Fig. 2. Stable oxygen isotope profiles along transects from umbo to shell edge and corresponding growth band patterns (grey bars = translucent zones in reflecting light) computed from umbo readings (assuming proportional band width in umbo and shell) in three individuals of *Eurhomalea exalbida*. (top) 12 y old, 72.8 mm shell height; (middle) 39 y old, 81.7 mm shell height; (bottom) 47 y old, 77.0 mm shell height. Width of the first growth band could not be measured owing to shell damage in the umbo region; hence the leftmost band in each plot refers to the second growth band in the shell. In the two older individuals some growth bands were spaced too narrowly to be plotted separately. Arrow indicates shell edge.

2.3. Mortality

Total mortality rate Z was estimated from the overall size-frequency distribution and the von Bertalanffy growth function parameters by a size-converted catch curve (Pauly, 1984a,b):

$$N_i / \Delta t_i = N_0 e^{-Z t_i} \quad (2)$$

where N_i is the number of individuals in size class i , Δt_i is the time required to grow through this size class and t_i is the relative age in the mid-size of class i . Total mortality Z is computed by the linear regression:

$$\ln(N_i / \Delta t_i) = a + b t_i; Z = -b \quad (3)$$

2.4. Production

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

$$P = \sum N_i \cdot M_i \cdot G_i \quad [g \text{ SFWM } m^{-2} y^{-1}] \quad (4)$$

N_i and M_i are the average number of animals ($N m^{-2}$) and mean individual body mass in size class i , and G_i is the mass-specific growth rate:

$$G_i = b \cdot K \cdot ((H_\infty / H_i) - 1) \quad [y^{-1}] \quad (5)$$

where b is the exponent of the size-mass relation, K , H_∞ are parameters of the von Bertalanffy function, and H_i is the mean size in class i . The mass specific growth rate G_i cannot be computed for any size $H_i \geq H_\infty$ of the underlying growth function. For size classes above H_∞ estimated by the von Bertalanffy function (see Results), we used the G_i of the last calculable size class. Production-to-biomass ratio (P/B) was computed by dividing P by the biomass B of the size-frequency sample.

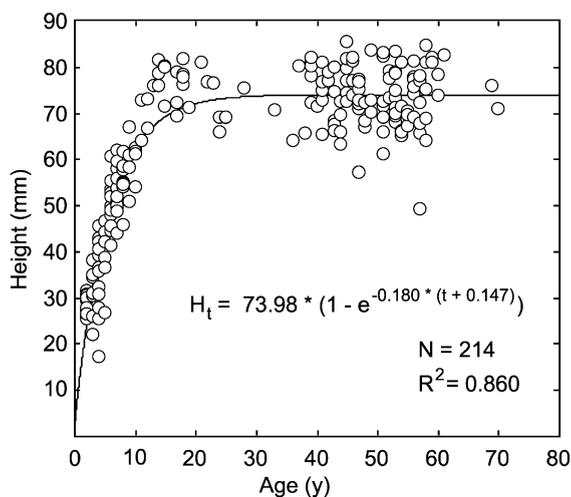


Fig. 3. Von Bertalanffy growth curve of *Eurhomalea exalbida* based on internal growth ring reading in 214 specimens.

3. Results

The fauna at the investigated site is virtually dominated by *E. exalbida*, but has not been studied systematically. Peculiar elements of the fauna are the bivalves *Mysella* sp., *Neolepton* sp., *Tawera gayi* and *Thracia meridionalis*, the snail *Natica* sp., and the decapods *Munida subrugosa* and *M. gregaria*. Generally the benthic fauna composition seems to be typical of similar shallow water sites of the Magellan region as described by various authors in Arntz and Ríos (1999).

Whole animal mass (TM), shell mass (SM), and shell free wet mass (SFWM) of *E. exalbida* are related to shell height (H) by:

$$\text{Log}(TM) = -3.460 + 2.903 \cdot \log(H);$$

$$N = 1045, r^2 = 0.991; p < 0.001$$

$$\text{Log}(SM) = -3.613 + 2.881 \cdot \log(H);$$

$$N = 1045, r^2 = 0.993; p < 0.001$$

$$\text{Log}(SFWM) = -4.111 + 3.021 \cdot \log(H);$$

$$N = 1173, r^2 = 0.994; p < 0.001$$

Under reflecting light, polished shell cuts showed a pattern of alternating broad opaque and narrow trans-

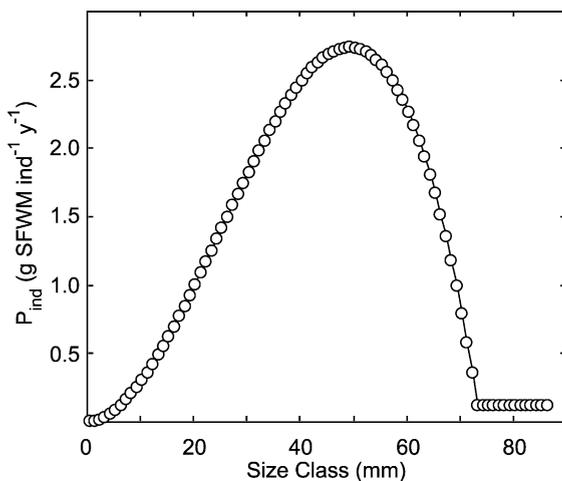


Fig. 4. Individual production (SFWM ind⁻¹ y⁻¹) versus height in *Eurhomalea exalbida*. Values for P_{ind} in size classes above $H_{\infty} = 73.98$ mm were set to the value of P_{ind} of the size class 73.5 mm.

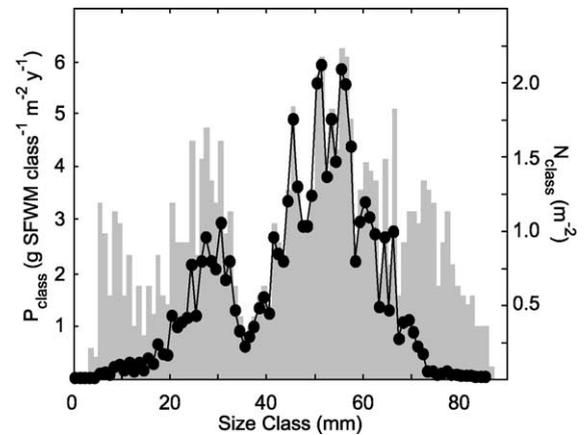


Fig. 5. Height-frequency distribution (bars, $N_{\text{class}}^{-1} \text{m}^{-2}$) and corresponding somatic production P_{class} distribution (dots, g SFWM class⁻¹ m⁻² y⁻¹) of *Eurhomalea exalbida*.

lucent bands, which were also confirmed by acetate peels. Stable oxygen isotopes were analysed in three individuals. $\delta^{18}\text{O}$ showed a consistent cyclic pattern. $\delta^{18}\text{O}$ peaks which indicated low water temperature coincided with the narrow translucent shell growth zones (Fig. 2). Obviously one translucent zone is

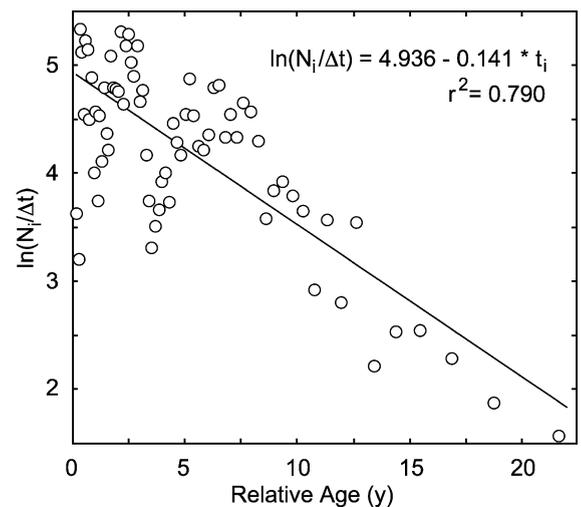


Fig. 6. Size-converted catch curve of *Eurhomalea exalbida* based on the overall size-frequency distribution and the von Bertalanffy growth function parameters. Regression includes size classes 4.5–73.5 mm.

formed each winter and hence individual age corresponds to the number of shell growth bands.

The 214 shell height-at-age data were fitted best by the von Bertalanffy function:

$$H_t = 73.98\text{mm} * (1 - e^{-0.180 * (t+0.147)});$$

$$N = 214; R^2 = 0.86$$

The maximum age reached was about 70 years (Fig. 3).

Individual production P_{ind} of *E. exalbida* depended on shell height (Fig. 4). P_{ind} increased steadily to 2.74 g SFWM y^{-1} at 49.5 mm shell height and then decreased. Animals between 40 and 70 mm shell height contributed most to the population somatic production of 134 g SFWM $\text{m}^{-2} \text{y}^{-1}$ (Fig. 5). Average population abundance was 83 ind m^{-2} and mean annual biomass amounted to 1123 g SFWM m^{-2} . Annual P/B ratio was computed to be 0.12 y^{-1} . In terms of ash-free dry mass, annual production and biomass amounted to 22.2 g AFDM $\text{m}^{-2} \text{y}^{-1}$ and 186.4 g AFDM m^{-2} , respectively (conversion factor of 0.166 taken from Brey, 2001).

Total mortality rate Z was estimated to be 0.14 y^{-1} by the size-converted catch curve (Fig. 6). The major recruitment peak occurred between November and February with smaller pulses the rest of the year (Fig. 7). On average 85 individuals <5 mm were counted per m^2 .

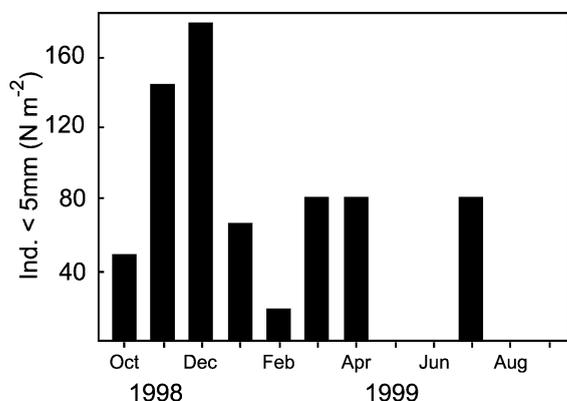


Fig. 7. Number of recruiting animals ($H < 5$ mm) collected from sediment samples between October 1998 and September 1999. Average density was 85 ind m^{-2} .

4. Discussion

Shell growth band patterns and $\delta^{18}\text{O}$ shell profiles indicate an annual cycle of shell growth in *E. exalbida* (Fig. 2). Direct measurements of growth in the field (obs. by first author) confirmed fast growth in spring (= opaque growth band) and slow or no growth during autumn and winter (= translucent growth band), as common in bivalves from temperate regions (e.g. Krantz et al., 1987).

The von Bertalanffy growth curve obtained from 214 height-at-age data

$$H_t = 73.98\text{mm} * (1 - e^{-0.180 * (t+0.147)})$$

indicated rapid growth up to an age of about 20 ($H_{20} = 72.0$ mm), whereas size growth was almost negligible during the remaining 50 years of life (Fig. 3). Urban and Tesch (1996) report similar growth parameter values ($H_t = 70.34$ and $K = 0.152$) for an intertidal population at San Juan, Magellan Strait, Chile, although they did not find individuals >13 years of age.

As to be expected from the population age and size structure (Figs. 3 and 5), both the observed P/B ratio of 0.12 y^{-1} and the observed mortality rate Z of 0.14 y^{-1} (Fig. 6, see Allen (1971) for long-term equivalence of P/B and Z) are comparatively low. Including the 85 ind m^{-2} of <5 mm (Fig. 7) in the production estimate would increase P/B by <1% only. The values of P/B and Z of *E. exalbida* are among the lowest reported for Venerid bivalves, but within the range of values reported for other hard clams such as *Venus antiqua* from Dichato Bay, Chile (Urban, 1996), *Callista brevisiphonata* from Peter the Great Bay, Japan (Selin and Selina, 1988) and *Mercenaria mercenaria* from Wassaw Sound, Georgia, USA (Walker and Tenore, 1984) (Fig. 8).

Regarding the relation between body mass and P/B, hard clams fit well into the superfamily Veneracea (Fig. 8), but it seems obvious that the common life strategy of this group is aimed at low mortality. This coincides with the comparatively low P/B ratio, high mean body mass and high mean age. The age structure of our *E. exalbida* population already indicates a comparatively low overall exploitation, especially in comparison with the population investigated by Urban and Tesch (1996). This population from the intertidal at San Juan, Chile, is exploited by local fishermen (J.

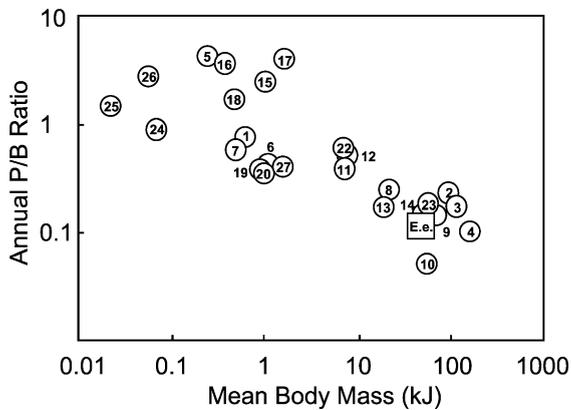


Fig. 8. Somatic productivity of *Eurhomalea exalbida* from Ushuaia Bay compared to other species of the superfamily Veneracea. The relation between P/B ratio and mean body mass M is described by $\log(P/B) = -0.1019 - 0.3853 \cdot \log(M)$, $N = 27$, $r^2 = 0.61$. Mass data were converted to kJ using conversion factors of Brey (1999, 2001) and references therein. 1: *Anomalocardia brasiliensis* (Monti et al., 1991), 2, 3, 4: *Callista brevisiphonata* (Selin and Selina, 1988), 5: *Chamelea gallina* (Ramón and Richardson, 1992), 6: *Chione cancellata* (Moore and Lopez, 1969), 7: *Dosinia hepatica* (Hanekom, 1986), 8, 9, 10: *Mercenaria mercenaria* (Walker and Tenore, 1984a), 11, 12, 13: *Mercenaria mercenaria* (Hibbert, 1976, 1977a,b), 14: *Protothaca thaca* (Urban and Campos, 1994), 15: *Tapes philippinarum* (Yap, 1977), 16, 17: *Venerupis decussata* (Guelorget et al., 1980), 18, 21: *Venerupis aurea* (Guelorget et al., 1980), 19, 20: *Venerupis aurea* (Hibbert, 1976), 22: *Venus antiqua* (Clasing et al., 1994), 23: *Venus antiqua* (Urban, 1996), 24, 25, 26: *Venus ovata* (Dauvin, 1985), 27: *Venus striatula* (Warwick et al., 1978), E.e.: *Eurhomalea exalbida* (this study).

Urban, pers. comm., 2002) and therefore lacks large animals of >45 mm almost completely. According to Brey and Gage (1997) the relative level of predation pressure on a particular population can be determined from the relation between mortality rate Z and growth constant K by the index:

$$\Delta_{Z/K} = \log(Z_{\text{measured}}/Z_{\text{predicted}});$$

$$-\infty \leq \Delta_{Z/K} \leq +\infty$$

Negative values indicate exploitation below, positive values above the empirically determined average level in benthic populations. $Z_{\text{predicted}}$ is derived from the empirical relation:

$$\log(Z_{\text{predicted}})$$

$$= 0.339 + 1.037 \cdot \log(\text{growth constant } K)$$

$\Delta_{Z/K}$ of *E. exalbida* amounts to -0.417 , which is among the lowest values encountered so far (see Brey

and Gage 1997). Obviously natural predators such as the muricid gastropods *Xymenopsis muriciformis* (King and Broderip, 1832) and *Trophon geversianus* (Pallas, 1774) are unable to prevent the population from over-ageing.

Our findings are in line with expectations for a population that is not subject to systematic and regular human exploitation. The infrequent traditional low-effort fishery we have some anecdotal evidence of seems to have no detectable effect. The lack of interest in a potentially valuable resource may be due partially to the frequent occurrence of red tides in the Beagle Channel, which makes molluscs from this area tricky to sell, and partially to the traditional prejudice of the Argentinean people against marine food. The population investigated by Urban and Tesch (1996) indicates that increased fishery pressure may be able to shift our population to a more productive yet stable state with a greater share of young, small and faster growing animals. This process would have to be controlled quite carefully to avoid over-exploitation, but fast growth during the first 20 years of their life and comparatively early maturity at 4 years of age (Morriconi et al., 2002) make *E. exalbida* more robust than other species with a similar life span. Nevertheless, the population age structure (Fig. 3) indicates that there have been extended periods of poor recruitment, e.g. 20–40 years ago, when whole age classes seem to be missing owing to yet unknown causes. High fishery pressure during such times could rapidly destroy this stock.

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