SHORT NOTE

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Antarctic scallop (*Adamussium colbecki*) annual growth rate at Terra Nova Bay

Abstract *Adamussium colbecki* is one of the most well-studied Antarctic molluscs. However, information on its growth rate is currently based on estimates from mark and recapture experiments and from growth-ring analyses. This paper provides the first estimates of the growth pattern of this scallop throughout a year, for individuals maintained under both natural field and laboratory conditions. Results show size-related differences in growth rate, both in the field and in aquaria, with scallops in Terra Nova Bay growing faster than those kept in aquaria. Growth performances were lower than those reported in the literature.

Introduction

Antarctic invertebrates are known to have very slow growth rates compared to their temperate counterparts, due to environmental conditions (temperature, light regime, food availability) that slow down metabolism, somatic and gonadic production. Due to the difficulty of performing long-term studies of growth rate in situ, much of the information regarding growth rates of Antarctic invertebrates is indirect, relying on estimates based on X-ray analysis of calcified structures or assessed through instantaneous growth rates measured through incorporation of markers (Brey et al. 1995; Dahm and Brey 1998; Peck et al. 1996).

Within the framework of the Italian (PNRA) project "The Marine Protected Area of Terra Nova Bay: short and long term variations", particular attention was focused on the scallop *Adamussium colbecki*, which is considered a key species in the Antarctic littoral ecosystem (Cattaneo-Vietti et al. 1999; Chiantore et al. 1998, 2000). The monitoring of the size-frequency distribution of different populations of this species in the area of Terra Nova Bay has stressed the dominance of large scallops, and spatially and temporally irregular recruitment (Chiantore et al. 2001). X-ray studies of shell indicate a growth rate of scallops up to the fifth ring of 8 mm year^{-1}, and for larger, sexually mature specimens of 5 mm year^{-1} (Cattaneo-Vietti et al. 1997).

The aim of this study was to provide absolute size-related annual growth rates of a widespread and conspicuous Antarctic species, both under laboratory and field conditions.

Between January 2000 and January 2001, two long-term experiments were performed to evaluate the growth rate of *A. colbecki*: a mark and recapture experiment, deploying a cage with 100 specimens, in order to evaluate the growth rate in field conditions at Terra Nova Bay, and an experiment in the laboratory with specimens transported to the aquaria of the Alfred Wegener Institute (AWI) laboratories of Bremerhaven (Germany), in order to compare field data with those from a controlled system.

Materials and methods

In summer 1999/2000, at the end of January, 100 *A. colbecki* specimens (ranging in shell length between 30 and 80 mm) were measured (shell length), marked (with small labels used for tagging bees, glued on the shell) and placed in a cage (iron frame: 100×50×30 cm; plastic net: 10 mm mesh size) deployed at 10 m depth, close to the Italian Station of Terra Nova Bay (TNB). Exactly 1 year later, the cage was recovered and the specimens measured. Unfortunately, only 27 out of the 100 specimens placed in the cage were recovered because the cage was seriously damaged by ice during the winter.

In the same period, around 100 specimens were measured and transported to the aquaria of the AWI in Bremerhaven, and maintained for over a year in cooled aquaria with recirculating seawater (0 ± 0.5°C, 33–34 psu) in a 12 h light:12 h dark daily light regime. The animals were fed twice a week by adding six Planktontabs

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(HOBBY, Dohse Aquaristik) dissolved in 500 cm³ seawater to each aquarium tank (each tab has a caloric value of 7.841 kJ ± 0.016). No deaths occurred after an acclimation period of 4 weeks (74 specimens remaining). After a year, these specimens were measured.

Growth parameters (L_∞, K) were estimated using Fabens' (1965) method by fitting a rearranged von Bertalanffy growth function (VBGF) to the obtained size increment data pairs using the NEWTON algorithm: $L_2 = L_1 + (L_\infty - L_1)\ (1 - e^{-K*dt})$, where L_∞ is the asymptotic length (mm), K is the growth constant (year^{-1}), L_1 is the length at the beginning and L_2 the length at the end of the time interval (dt). For t_0, no estimate can be obtained from growth-increment data.

Preliminary results for the data from TNB showed that L_∞ deviated considerably from the largest individual present in the population (L_{max}). To avoid this bias, caused by a data set not covering the whole size-range of the population (see also Gröger 2000), L_∞ was fixed to L_{max} (= 92 mm) for the final calculation.

However, growth parameters derived from size-increment data are not directly comparable with parameters obtained from size-age data (for a detailed discussion see Francis 1988, 1995; Sainsbury 1980). Therefore, the overall growth-performance index Ψ, calculated by maximum body mass and maximum age (Brey 1999) was used for growth comparison with previously published data.

Results and discussion

Length-growth data of specimens in the field and in captivity are reported in Table 1. The two data sets regarding in situ and aquaria growth rates are not equally represented in terms of size distribution. The aquaria data set is mainly constituted by small individuals, while field data are from a few small individuals and a larger number of big scallops, and middle-size class individuals are virtually absent.

Growth rate of specimens in situ is strongly size dependent with high inter-individual variability. In fact, Fig. 1 and Table 1 show that the in-situ growth rate is higher for smaller individuals (< 50 mm in shell length), showing an average growth rate of 10 mm year^{-1} compared to 0.8 mm year^{-1} for larger specimens.

Growth rates in aquaria are slower than in the field, at least for young specimens, notwithstanding the continuous food supply (Fig. 1). As sexual maturity occurs

Table 1 Growth rate (mm year^{-1}, avg ± SD) of *Adamussium colbecki* specimens in the field and in aquaria

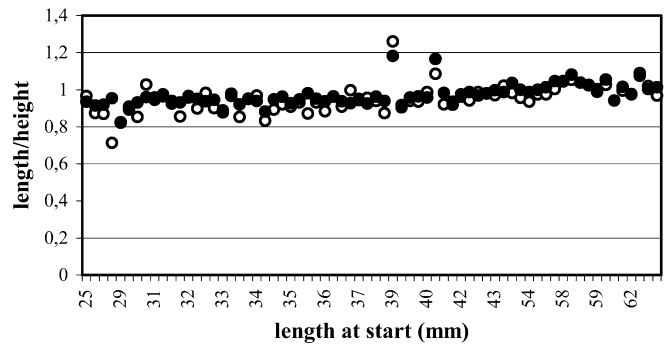| Length class (mm)	Field data		Laboratory data	
	Specimens N	Growth rate	Specimens N	Growth rate
20–30			6	4.8 ± 2.1
31–40	2	13.2 ± 0.8	35	4.5 ± 1.5
41–50	3	8.5 ± 1.5	10	3.4 ± 0.6
51–60	1	2.8	11	3.2 ± 1.3
61–70	3	1 ± 0.7	5	2.8 ± 0.9
71–80	13	0.4 ± 0.3		
81–85	5	0.7 ± 0.4		

Fig. 2 Ratio between shell length and height for specimens kept in aquaria, measured at the beginning (*unfilled circles*) and at the end (*filled circles*) of the experiment

at a size of about 50 mm in shell length, it is possible that captivity could affect smaller size classes more than larger ones, eventually delaying reproductive maturity. Nonetheless, the length-dependent ratios between length and height of the shell measured at the start and at the end of the captivity experiment show similar trends, with values at the end slightly higher than at the start (*t*-test, $p < 0.05$; Fig. 2). This suggests that animals growing in

Fig. 1 Size-dependent annual growth rate of *Adamussium colbecki* in situ (*a*) and in aquaria (*b*). Polynomial formulas are reported for both fitting curves

$y = 0.0078x^2 - 1.1795x + 44.985$
$R^2 = 0.9541$

$y = 0.0025x^2 - 0.3001x + 11.788$
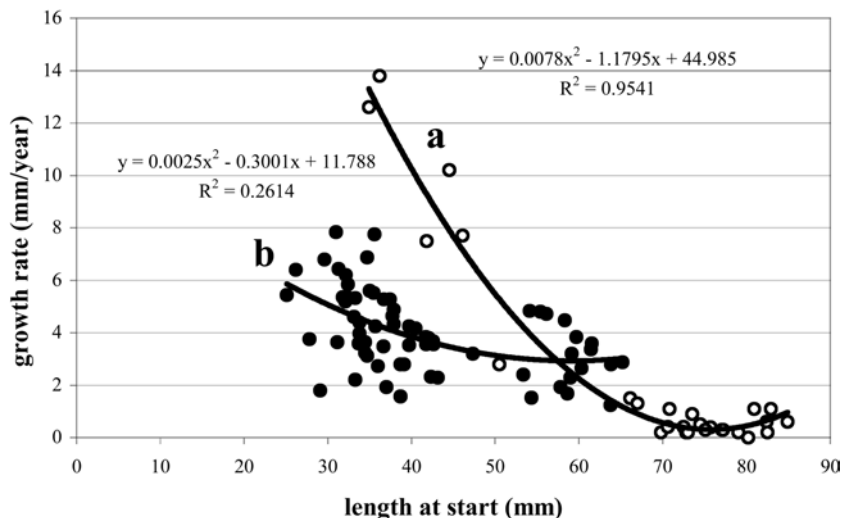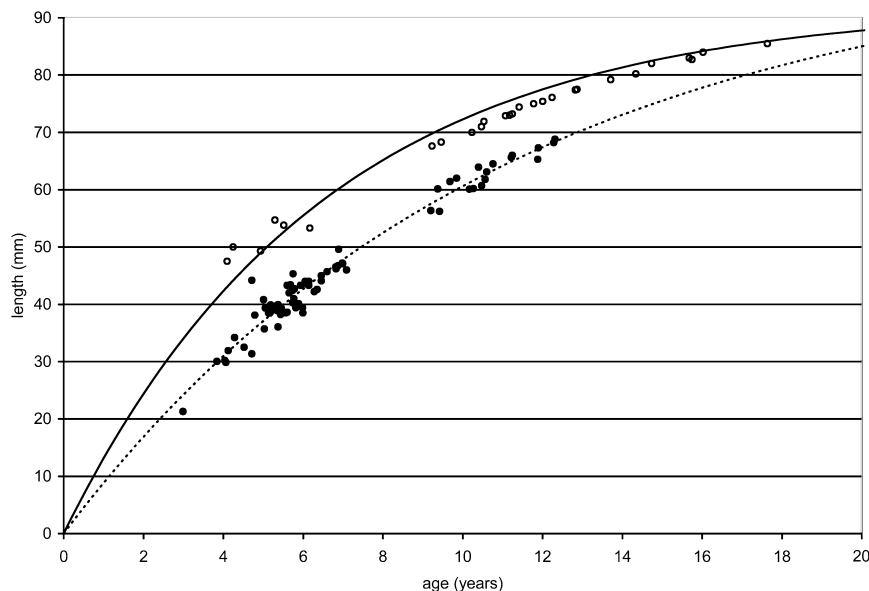$R^2 = 0.2614$

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Fig. 3 Growth curves of the von Bertalanffy growth function of *Adamussium colbecki* estimated from two data sets: in situ (*circles*) and in aquaria (*points*) (growth parameters are given in Table 2)

the aquaria increase in length relative to the height of the shell. As this ratio may be used as an indicator of sexual maturity in natural populations (Ansell et al. 1998; Cattaneo-Vietti et al. 1997), a regular growth pattern in captivity may be inferred.

The calculated VBGF growth curves (Fig. 3) show a faster growth of *A. colbecki* under in-situ conditions compared to growth in aquaria. This is stressed by the overall growth performance (Table 2). However, in both experimental set-ups, the growth performance for *A. colbecki* is smaller than in previously published studies, based on less direct measures of growth rate. Both Stockton (1984) and Berkman (1990) reported that yearly growth increment decreases with size. The different growth efficiencies displayed in Terra Nova Bay and New Harbor populations may be due to methodological differences (ring counting instead of direct repeated measurements), but could also mirror differences in habitat and productivity of the two areas, confirming that Antarctic marine invertebrates are food limited rather than temperature limited (Clarke 1993).

Such results are extremely useful for making productivity and energy-budget estimates of populations. In particular, Terra Nova Bay populations, studied for more than 10 years, show not only different features from site to site, but also sudden increases or decreases

in dominance of larger size classes, because of strong spatially and temporally varying recruitment events (Chiantore et al. 2001). Consequently, the use of growth parameters will stress discrepancies between real and predicted data. They allow production estimates to be made at different sites and help to evaluate biomass changes to be interpreted on the basis of intermittent recruitment, size selective predation or, eventually, migration and displacement.

The discrepancies between growth performances in situ and captivity suggest that throughout the year trophic conditions at Terra Nova Bay are not or only a little food limited (quantitatively and/or qualitatively) for scallop growth: lateral advection and resuspension (Ansell et al. 1998) of organic material should provide enough food for growth rates that were higher than under captivity conditions with a continuous food supply.

Table 2 Parameters of von Bertalanffy growth function and overall growth performance Ψ for *Adamussium colbecki*. Data from Stockton and Berkman are from Explorers Cove (New Harbor)

Location	$L\infty$ (mm)	K (year^{-1})	Ψ	Reference
BHV	101.4	0.091	0.74	This study
TNB	92.0	0.154	0.84	This study
TNB	108.9	0.114	0.93	Heilmayer et al. (2003)
McMurdo Sound	105.0	0.120	1.03	Stockton (1984)
McMurdo Sound	128.0	0.090	1.20	Berkman (1990)

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