SEASONAL PERIODICITY OF GROWTH AND COMPOSITION IN VALVES OF *DIPLODON CHILENSIS PATAGONICUS* (D'ORBIGNY, 1835)

A.L. SOLDATI[1], D.E. JACOB[1], B.R. SCHÖNE[1], M.M. BIANCHI[2] AND A. HAJDUK[3]

[1]*Department of Geosciences, Johannes Gutenberg-Universität Mainz, Becherweg 21, D-55099 Mainz, Germany;*
[2]*INIBIOMA - CONICET, Universidad Nacional del Comahue, Quintral 1250, CP8400 San Carlos de Bariloche, Argentina; and*
[3]*CONICET, Museo de la Patagonia, Centro Cívico CP8400, San Carlos de Bariloche, Argentina*

(Received 6 May 2008; accepted 3 November 2008)

ABSTRACT

Freshwater mussels of the genus *Diplodon* (Unionida) are common inhabitants of lakes and rivers in South America, and have slow growth and long life spans. We established the annual periodicity of incremental shell growth in *Diplodon chilensis patagonicus* (d'Orbigny, 1835) and calculated growth rates at different ages, using internal ring counting supported by dyeing methods and $\delta^{18}O$ isotope analyses, in two Patagonian populations (Lago Steffen and its effluent Río Manso Inferior, Argentina). Longevities of ca. 90 years (Lago Steffen) significantly extend the life spans reported in the past. Growth rates for old individuals (>30 years) from both lake and river populations average 0.16 mm per year along the axis of minimal growth. We evaluated the seasonal periodicity of minor and trace elements (Mn, Mg, Sr, Ba, Na, S) *in situ* by Laser Ablation ICP-MS and Electron Probe Microanalyser analyses. Line-scans in a valve from Lago Steffen show that Mn, Sr and Ba are preferentially accumulated during the summer, while higher concentrations of Mg are found in the winter bands. Metal/Ca ratios may serve as long-term archives of environmental variables, e.g. metal concentrations in water, water temperature and primary productivity. *Diplodon chilensis patagonicus* valves exhibit excellent characteristics to construct an accurate chronological archive with time windows of up to around a century, resolving the environmental signal annually and even seasonally.

INTRODUCTION

The soft parts of mussels and ground shells are widely used to monitor trace metal abundance and bioavailability in ecosystems (e.g. Bertine & Goldberg, 1972; Koide, Lee & Goldberg, 1982; Brooks & Rumsby, 1984; Phillips & Rainbow, 1988; Odzak *et al*., 1994). They have also been used successfully to characterize the environment, for example to detect heavy metal contamination and radionuclides (e.g. Koide *et al*., 1982; Bourgoin, 1990; Hameed *et al*,. 1993; Lau *et al*., 1998; Brauer *et al*., 2001; Sokolowski, Wolowicz & Hummel, 2007) or to monitor human impact (e.g. Brown & Luoma, 1995; Puente *et al*., 1996; Lau *et al*., 1998; Szefer *et al*., 2002; Cardellicchio *et al*., 2008). Nevertheless, studies on homogenized material (tissues or ground shells) do not provide temporal resolution, but only time-averaged information. In contrast, spatially resolved data on mussel shells provides information that has the potential to resolve the time scale annually, seasonally, fortnightly, daily and even sub-daily (Clark, 1974; Lutz & Rhoads, 1980).

Bivalve molluscs form their shell by periodic accretion of calcium carbonate ($CaCO_3$) and organic substances (sugars and proteins) from the extrapallial fluid at the biomineralization front (Addadi *et al*., 2006). This fluid is situated between the outer mantle epithelium and the inner shell surface, and its composition may be determined by both the composition of the surrounding water and the metabolic processes in the mussel (Crenshaw, 1980). Under normal environmental conditions, this process is regulated by rhythmic physiological parameters, known as 'biological clocks' (e.g. Palmer, 1970) and by external cyclic events such as light, tidal or temperature cycles (Thompson, 1975). They can result in distinct periodic (daily, tidal, seasonal, annual, etc.) 'growth lines' in the shell (Clark, 1974). In addition to these natural cycles and rhythms, abnormal environmental conditions, such as high summer temperatures, storms, etc. may also produce 'disturbance lines' (Clark, 1974). In many cases growth lines and disturbance lines may be helpful to create an internal scale to date exactly the time axis of each part of the shell, i.e to order chronologically the information recorded in the shell (e.g. Rhoads & Panella, 1970; Hudson *et al*., 1976).

Variation of environmental parameters such as food supply, substratum type, salinity, illumination, temperature, concentration of dissolved oxygen or oxygen/carbon dioxide ratio, among others, may affect growth pattern, shell structure, mineralogy, isotopic fractionation and chemistry (Rhoads & Panella, 1970; Bertine & Goldberg, 1972; Meenakshy *et al*., 1974; Eisma, Mook & Das, 1976; Carter, 1980; Lutz & Rhoads, 1980; Brooks & Rumsby, 1984). Thus, shell features, minor and trace element composition patterns and isotopic signals may serve as an archive of environmental history (e.g. Schöne *et al*., 2007). Using the incremental growth patterns as a calendar, the chemical data archived in the shell can be chronologically aligned, thereby vastly extending the performance of the animal as a long-term water quality and environmental monitor (recent samples), and even as a palaeoecological and palaeoclimate recorder (fossil samples) (Rhoads & Lutz, 1980). The potential of bivalve shells for environmental reconstructions is increasingly recognized, but most studies have focused on marine species (e.g. Steuber, 1999; Dutton, Lohmann & Zinsmeister, 2002; Schöne *et al*., 2002, 2003, 2005b; Schöne, 2003; Steuber *et al*., 2005; Pearce & Mann, 2006), while freshwater mussels have been less frequently investigated (e.g. Nyström *et al*., 1995; Tevesz,

Correspondence: A.L. Soldati; email: soldatia@uni-mainz.de

Journal of Molluscan Studies (2009) ***75****: 75–85. Advance Access Publication: 22 December 2008* *doi:10.1093/mollus/eyn044*