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Ba/Ca ratios in shells of *Arctica islandica*—Potential environmental proxy and crossdating tool

Soraya Marali [a], Bernd R. Schöne [a,*], Regina Mertz-Kraus [a], Shelly M. Griffin [b], Alan D. Wanamaker Jr [b], Una Matras [c], Paul G. Butler [d]

[a] Institute of Geosciences, Johannes Gutenberg University, Johann-Joachim-Becher-Weg 21, 55128 Mainz, Germany
[b] Department of Geological and Atmospheric Sciences, Iowa State University, 253 Science I, Ames, IA 50011, USA
[c] Faroe Marine Research Institute, Nóatún 1, P.O. Box 3051, FO 110 Tórshavn, Faroe Islands
[d] School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, UK

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ABSTRACT

Ba/Ca_{shell} time-series of marine bivalves typically show flat background levels which are interrupted by erratic sharp peaks. Evidence from the literature indicates that background Ba/Ca_{shell} ratios broadly reflect salinity conditions. However, the causes for the Ba/Ca_{shell} peaks are still controversial and widely debated although many researchers link these changes to primary productivity, freshwater input or spawning events. The most striking feature is that the Ba/Ca_{shell} peaks are highly synchronous in contemporaneous specimens from the same population. For the first time, we studied Ba/Ca_{shell} in mature and ontogenetically old (up to 251 year-old) specimens of the long-lived *Arctica islandica*. Also, we analyzed specimens from surface water and deeper water. The typical pattern of low background and erratic peaks persisted throughout ontogeny. However, due to decreasing sampling resolution and greater time-averaging in older, slower growing shell portions, the background Ba/Ca_{shell} values appeared to gradually increase with ontogenetic age, whereas the peaks became attenuated and broader. Despite that, Ba/Ca_{shell} maxima were still highly synchronous among contemporaneous specimens from the same locality and habitat confirming previous reports from short-lived species. Computing of annual Ba/Ca_{shell} averages largely eliminated any bias introduced by time-averaging and sampling resolution. Strongly elevated annual Ba/Ca_{shell} peaks in specimens from surface waters (Iceland, Faroe Islands, Isle of Man) during the 1980s appear to coincide with an extreme primary productivity pulse recorded by remote sensing. However, due to the lack of in vivo experiments, we cannot ultimately test a causal link between annual Ba/Ca_{shell} excursions and primary productivity. We propose that Ba/Ca_{shell} time-series, specifically the highly synchronous Ba/Ca_{shell} peaks and annual Ba/Ca_{shell} values in contemporaneous specimens from the same locality can serve as a tool to verify crossdating and facilitate the construction of statistically robust growth increment width master chronologies. Long-term environmental reconstructions based on bivalve shell growth chronologies can likely greatly benefit from this new technique.

1. Introduction

In recent years, bivalve shells have attracted much attention as high-resolution recorders of past climate change (Wanamaker et al., 2011; Schöne and Gillikin, 2013). Information on environmental conditions that prevailed during growth such as seawater temperature, food availability etc. is preserved in the shells, for example, in the form of variable increment widths (faster growth at optimal temperatures and when more food is available) and $\delta^{18}O_{shell}$ values. These environmental proxy data can be placed in a precise temporal context by careful visual inspection, and counting annual and daily growth increments and lines. Based on similar growth patterns (wiggle-matching or crossdating, Douglass, 1941) it is also possible to combine annual growth increment width time-series of specimens with overlapping lifespans to form stacked chronologies or master chronologies.[1] This method was first established in dendrochronology (Douglass, 1914) and later applied to bivalve shells (Jones et al., 1989; Black et al., 2008, 2015). Master chronologies can cover many centuries to millennia and in combination with environmental proxies, provide information on the climate history over

[1] We use the term 'master (stacked) chronology' for a statistically robust (*EPS* value >0.85; Wigley et al., 1984) stacked record of crossdated growth increment width time-series. In contrast, a 'stacked chronology' or 'stacked record' (without 'master') is less well replicated and/or has an *EPS* < 0.85. In previous works, the latter has also been referred to as 'composite chronology' (Schöne, 2013). Since the connotation of this term is different in the field of dendrochronology, we refrain from using it here again. The terms 'time-series' and 'chronology' are used synonymously and denote a sequence of increment width data arranged in time.

* Corresponding author.
E-mail address: schoeneb@uni-mainz.de (B.R. Schöne).

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