



Strontium/lithium ratio in aragonitic shells of *Cerastoderma edule* (Bivalvia) – A new potential temperature proxy for brackish environments

Christoph S. Füllenbach, Bernd R. Schöne*, Regina Mertz-Kraus

Institute of Geosciences, University of Mainz, Joh.-J.-Becher-Weg 21, 55128 Mainz, Germany

ARTICLE INFO

Article history:

Received 11 June 2015

Received in revised form 16 October 2015

Accepted 19 October 2015

Available online 20 October 2015

Keywords:

Bivalve shell

Temperature proxy

Element-to-element ratio

Strontium

Lithium

ABSTRACT

Quantitative reconstruction of water temperature from shells of bivalve mollusks is still a very challenging task. For example, in highly variable environments such as intertidal zones, shell oxygen isotope values can only provide reliable temperature estimates if the $\delta^{18}\text{O}_{\text{water}}$ signature during the time of growth is known. Furthermore, trace element-to-calcium ratios such as Sr/Ca or Mg/Ca often do not serve as reliable paleothermometers, because their incorporation into bivalve shells is known to be strongly biologically controlled. Here, we present a potential novel temperature proxy which is based on the Sr/Li_{shell} ratio of the intertidal bivalve *Cerastoderma edule*. Up to 81% of the variability in Sr/Li_{shell} is mathematically explained by water temperature. It is suggested that vital effects on the incorporation of Sr and Li into the aragonitic shells are largely eliminated by normalizing Sr/Ca to Li/Ca. Growth rate does not control the incorporation of Sr or Li into the shell of *C. edule*. By using this new proxy, it was possible to estimate water temperature from *C. edule* with an uncertainty of ± 1.5 °C. Future studies are required to test if Sr/Li_{shell} also serves as a reliable temperature proxy in other bivalve species and in other environments.

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1. Introduction

Bivalve shells are becoming increasingly recognized as powerful tools for high-resolution paleoclimate reconstructions. This class virtually combines all requirements of an ideal paleoclimate archive. Bivalves inhabit nearly all aquatic environments, specifically extratropical shallow-marine and nearshore settings (Nicol, 1951; Lomovskiy et al., 2002; Malham et al., 2012). During growth these animals store information on changes of the physico-chemical environment in their shells in the form of variable growth rates and geochemical properties (Williams et al., 1982; Chauvaud et al., 2005; Wanamaker et al., 2008; Hallmann et al., 2011). Environmental proxy data can be placed in a precise temporal context by using periodic shell growth patterns, i.e., circatidal, daily, fortnightly and annual growth increments and lines (Evans, 1972; Jones, 1983; Ohno, 1985; Jones and Quitmyer, 1996). Certain boreal species are known to grow shell during both seasonal extremes and thus record the full seasonal amplitude (Schöne et al., 2005a). Some bivalves are exceptionally long-lived and attain a lifespan of more than 500 years (Schöne et al., 2005a; Wisshak et al., 2009; Butler et al., 2013). Therefore, bivalves can provide subseasonally resolved records of environmental change over coherent time intervals of many years (Schöne et al., 2005b; Wanamaker et al., 2011; Yan et al.,

2015). Since shell growth of contemporaneous specimens from the same region is highly synchronized, it is also possible to combine annual growth increment time-series to form longer chronologies that cover many generations of bivalves and centuries to millennia (Witbaard et al., 1997; Marchitto et al., 2000; Butler et al., 2010, 2013; Holland et al., 2014).

Despite recent achievements in bivalve sclerochronology, quantitative reconstructions of environmental variables from shells still remain a very challenging task. This is particularly true for ocean temperature, a crucial parameter of the climate system. The most frequently used and well-accepted proxy for water temperature, $\delta^{18}\text{O}_{\text{shell}}$, provides reliable temperature data only if the oxygen isotope signature of the water or salinity, which is strongly coupled to $\delta^{18}\text{O}_{\text{water}}$, during the time of growth is precisely known (Epstein et al., 1953; Mook, 1971; Grossman and Ku, 1986; Wefer and Berger, 1991). For bivalves, however, no proxy exists for $\delta^{18}\text{O}_{\text{water}}$ or salinity. More recently, the carbonate clumped isotope method has been introduced as a novel paleothermometer (Ghosh et al., 2006; accuracy ca. ± 1.4 °C) and has already been successfully applied to bivalves (Came et al., 2007; Eagle et al., 2013; Henkes et al., 2013). However, Eiler (2011) suggested that Δ_{47} values of biogenic carbonates are biased by vital effects. Even if this effect can be mathematically eliminated, the low sample throughput (~six measurements per 24 h; at least triplicate measurements are required for one sample) and the relatively large amounts of shell carbonate required for each analysis (ca. 1.2 to 4 mg per measurement)

* Corresponding author.

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