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Venerid bivalve *Venus verrucosa* as a high-resolution archive of seawater temperature in the Mediterranean Sea

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ABSTRACT

High-resolution stable isotope data ($\delta^{18}O$, $\delta^{13}C$) were used to study growth strategies of the bivalve *Venus verrucosa* collected from three sites of the eastern coast of the Adriatic Sea. The principal objectives of this study were to identify the main growing season and to evaluate the potential applicability of $\delta^{18}O_{shell}$ values to reconstruct the seasonal temperature variability. Calcium carbonate for oxygen and carbon isotope analyses was obtained by drilling the outer shell layer. Temporal and spatial variations in temperature and salinity values at the study sites were simulated using the 3D numerical ocean model ROMS. Annual periodicity of growth patterns was confirmed by $\delta^{18}O_{shell}$ cycles which corresponded to the number of observed seasonal growth marks. Temporal alignment of stable oxygen data with modelled seawater temperature data indicates that *V. verrucosa* deposits shell material from March/April to December. Shell growth slowdown and/or cessation occurred between late winter and early spring when the seawater temperature dropped below 12 °C at the two northern sites, Istria and Pag Bay, and below 13 °C at the southern site, Kaštela Bay. Summer temperatures reconstructed from *V. verrucosa* agreed well with modelled summer temperatures, but lowest reconstructed temperatures were consistently higher than the modelled winter values. The range of $\delta^{18}O_{shell}$ values obtained from *V. verrucosa* shells is higher than the range obtained previously from other species in the eastern Adriatic Sea, indicating the high potential of *V. verrucosa* for temperature reconstructions.

1. Introduction

Bivalve shells are valuable archives of past environmental conditions as analysis of their geochemical properties offers insights into one or more environmental variables occurring at the time when the shells were formed (e.g., Jones, 1983; Marchitto et al., 2000; Schöne, 2008). The stable oxygen isotope value of shell carbonate ($\delta^{18}O_{shell}$) is a well-established palaeothermometer that allows high-resolution reconstructions of seawater temperatures (e.g., Schöne and Gillikin, 2013; Gutiérrez-Zugasti et al., 2015). However, as the shell growth rate is not constant (e.g., Jones and Quitmyer, 1996; Vihtakari et al., 2016), growth cessations prevent bivalves from providing uninterrupted records of environmental conditions (Goodwin et al., 2003). To make the reconstruction of environmental conditions reliable and to facilitate the interpretation of intra-annual geochemical proxy records, bivalves from wide taxonomic and ecological ranges should be used along with the knowledge of species-specific growth patterns and their seasonality (Chauvaud et al., 2005; Schöne et al., 2005).

Knowledge of the past environmental variation is crucial to understand the importance of possible future changes (Chauvaud et al., 2005) and for this purpose, detailed records of oceanic conditions across a variety of temporal and spatial scales are needed (Grebmeier, 2012; Vihtakari et al., 2016). Numerous studies on global climate change indicate the vulnerability of the Mediterranean Sea region, predicting it will become substantially warmer and drier (e.g., Giorgi and Lionello, 2008; Adloff et al., 2015; Planton et al., 2016; Lionello and Scarascia, 2018). Mean temperatures in this region are expected to increase at a faster rate than the global mean temperature, particularly during the summer period (Lionello and Scarascia, 2018). In the Mediterranean Sea, there is still a relatively small number of studies that analysed the possible usage of stable isotope data in shell carbonate for the reconstruction of environmental conditions. Some previous studies, including Bušelić et al. (2015) on *Glycymeris bimaculata* and Peharda et al. (2015) on *Lithophaga lithophaga*, obtained $\delta^{18}O_{shell}$ data but used it primarily to validate the timing of growth line formation. Examples of

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