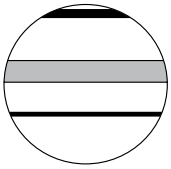

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Oxygen and carbon stable isotopes of *Mytilus galloprovincialis* Lamarck, 1819 shells as environmental and provenance proxies

Stefania Milano,[1,2] Bernd R Schöne[2] and Igor Gutiérrez-Zugasti[3]

Abstract

Mollusc shell stable isotopes are commonly used to reconstruct past environmental conditions. However, despite being abundant components of natural and anthropogenic fossil accumulations, the geochemical composition of mussel shells (*Mytilus* spp.) has rarely received attention in palaeoenvironmental studies. This study tests the suitability of oxygen isotopes ($\delta^{18}O_s$) of *Mytilus galloprovincialis* as palaeothermometer. For 1 year, mussels and water samples were collected twice a month from Berria Beach, in Northern Spain. The geochemical data of the shells indicate that water temperatures can be reconstructed with an average offset of 1.2 ± 0.7°C with respect to the measured values. Furthermore, no prolonged shell growth cessations are observed. These results validate *M. galloprovincialis* as reliable recorders of seasonal water temperature fluctuations, supporting their use in palaeoenvironmental studies. In addition, further shell and water collections were carried out in the upper and lower areas of a nearby estuary. The geochemical analyses of these shells were aimed to test whether oxygen and carbon stable isotopes ($\delta^{13}C_s$) may be used as novel proxies to identify the shell provenance at local scale. The results show that the $\delta^{18}O_s$ versus $\delta^{13}C_s$ correlation direction varies along the coast–upper estuary geographical gradient, suggesting it to be a potential new proxy to distinguish between marine and estuarine mussel specimens.

Keywords

geochemistry, Mediterranean mussel, Northern Spain, palaeoenvironmental reconstructions, provenance, proxy calibration

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Introduction

Mollusc shells are abundant remains in palaeontological and archaeological accumulations worldwide. Their presence reflects both their extraordinary preservation potential and their tight connection with the evolution of our species since prehistoric times. In fact, besides natural aggregations, numerous archaeological sites contain large amounts of shell remains ('shell middens'). In human history, molluscs have played an important role primarily as easily accessible food resources and also as raw materials for various types of artefacts such as personal ornaments and tools, for example, scrapers and fish hooks (Flores et al., 2016; Marean et al., 2007; Vanhaeren and D'Errico, 2005).

The geochemical properties of the shell calcium carbonate offer insights into the environmental conditions occurring at the time when the shells were built by the molluscs (Jones, 1983; Marchitto et al., 2000; Schöne, 2008). Among the different existing proxies, the oxygen stable isotope ratio of marine shells ($\delta^{18}O_s$) is a well-established palaeothermometer that allows highly resolved water temperature reconstructions during time intervals prior to any instrumental record (Gutiérrez-Zugasti et al., 2015; Schöne and Gillikin, 2013). The incorporation of oxygen isotopes from the surrounding water into the shell is a temperature-dependent fractionation process. Through specific equations using the oxygen isotope value of the water ($\delta^{18}O_w$) and the $\delta^{18}O_s$, accurate estimations of the water temperature at the time of shell deposition are achieved (Epstein et al., 1953; Grossman and Ku, 1986).

Molluscs deposit the shell throughout their life. By using a high-resolution sampling approach on individual shells, it is possible to reconstruct the water temperature fluctuation at annual, seasonal and even weekly resolution (Gutiérrez-Zugasti et al., 2015; Hallmann et al., 2009; Schöne et al., 2004). Furthermore, the temperature reconstruction of the last shell portion formed just before death can give important information in archaeological contexts as it can be used to determine the season of shellfish collection and therefore human dietary habits (Burchell et al., 2013; Mannino et al., 2007; Prendergast et al., 2016).

Although *Mytilus* spp. are abundant in the archaeological record, there is a lack of specific modern calibration studies testing the suitability of representatives of this genus for palaeoenvironmental reconstructions. The current study is based on modern

[1]Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Germany
[2]Institute of Geosciences, Johannes Gutenberg University of Mainz, Germany
[3]Universidad de Cantabria, Gobierno de Cantabria, Banco Santander and Instituto Internacional de Investigaciones Prehistóricas de Cantabria, Spain

Corresponding author:
Stefania Milano, Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany.
Email: stefania_milano@eva.mpg.de