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Growth-increment characteristics and isotopic ($\delta^{18}O$) temperature record of sub-thermocline *Aequipecten opercularis* (Mollusca:Bivalvia): evidence from modern Adriatic forms and an application to early Pliocene examples from eastern England

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ABSTRACT

The shell $\delta^{18}O$ of young modern *Aequipecten opercularis* from the southern North Sea provides an essentially faithful record of seasonal variation in seafloor temperature. In this well-mixed setting, *A. opercularis* shell $\delta^{18}O$ also serves as a proxy for seasonal variation in surface temperature. Individuals from less agitated (e.g. deeper) settings in a warm climate would not be expected to record the full seasonal range in surface temperature because of thermal stratification in summer. Such circumstances have been invoked to explain cool isotopic summer temperatures from early Pliocene *A. opercularis* of eastern England. Support for a sub-thermocline setting derives from high-amplitude variation in microgrowth-increment size, which resembles the pattern in sub-thermocline *A. opercularis* from the southern Mediterranean Sea. Here, we present isotope and increment profiles from further sub-thermocline individuals, live-collected from a location in the Adriatic Sea for which we provide modelled values of expected shell $\delta^{18}O$. We also present data from supra-thermocline shells from the English Channel and French Mediterranean coast. The great majority of sub-thermocline *A. opercularis* show high-amplitude variation in increment size, and winter and summer $\delta^{18}O$ values are generally quite close to expectation. However, the relatively warm summer conditions of 2015 are not recorded, in most cases due to a break in growth, perhaps caused by hypoxia. The supra-thermocline shells show subdued increment variation and yield isotopic winter and summer temperatures quite close to the local directly measured values. *A. opercularis* shells therefore provide a fairly good isotopic record of ambient temperature (if not always of relatively warm summer conditions below the thermocline) and their hydrographic setting can be determined from increment data. Early Pliocene examples from eastern England can be interpreted as having lived in a setting below the thermocline, with a higher seasonal range in surface temperature than now in the adjacent southern North Sea.

1. Introduction

The $\delta^{18}O$ of skeletal $CaCO_3$ (calcite and aragonite) is very widely used as a proxy for the temperature of the ambient environment; in particular, the $\delta^{18}O$ of marine mollusc shells is used as an indicator of seawater temperature (e.g. Schöne and Surge, 2005; Schöne and Gillikin, 2013; Prendergast et al., 2017; Gillikin et al., 2019). The values obtained are often presented as if they reflect sea-surface temperature, a datum of great interest to climatologists and palaeoclimatologists, but those derived from benthic taxa such as bivalves are of course a record of seafloor temperature (with the additional influence of water $\delta^{18}O$, which must be measured or estimated to enable calculation of temperature from shell $\delta^{18}O$). In agitated settings (where the seafloor is above the fair-weather wave-base, or to somewhat greater

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