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Comparative sclerochronology of modern and mid-Pliocene (c. 3.5 Ma) *Aequipecten opercularis* (Mollusca, Bivalvia): an insight into past and future climate change in the north-east Atlantic region

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ABSTRACT

Records of environment contained within the accretionarily deposited tissues of fossil organisms afford a means of detailed reconstruction of past climates and hence of rigorous testing of numerical climate models. We identify the environmental factors controlling oxygen and carbon stable-isotopic composition, and micro-growth-increment size, in the shell of modern examples of the Queen Scallop, *Aequipecten opercularis*. This understanding is then applied in interpretation of data from mid-Pliocene *A. opercularis* from eastern England. On the basis of oxygen-isotope evidence we conclude that winter minimum seafloor temperature was similar to present values (typically 6–7 °C) in the adjacent southern North Sea and that summer maximum seafloor temperature was a few degrees lower than present values (typically 16–17 °C). This contrasts with evidence from other proxies that winter and summer temperatures were higher than present. The pattern of seasonal variation in microgrowth-increment size suggests the existence of intense thermal stratification in summer. We therefore conclude that summer surface temperatures were much higher (maxima well over 20 °C) than those recorded isotopically on the seafloor and that the annual range of surface temperature (probably over 14 °C) was greater than now at the times in the mid-Pliocene when the investigated *A. opercularis* were alive. Taken in conjunction with other proxy evidence of warmer winters as well as summers, the data point to substantial fluctuation (up to 10 °C) in winter minimum temperatures during the mid-Pliocene in the north-east Atlantic region. This fluctuation may be attributable to variation in the strength of the Gulf Stream/North Atlantic Drift. Since the Pliocene has been widely used as a test-bed for numerical models of a greenhouse Earth, the results have implications for prediction of future climate in the north-east Atlantic region under the influence of anthropogenic global warming.

1. Introduction

Sclerochronology (Buddemeier and Maragos, 1974) is the study of time-series data contained within the accretionarily deposited mineral tissues of plants (e.g. the skeletal materials of certain multicellular algae) and animals (e.g. the shells of many invertebrates). As in the longer-established sister-field of dendrochronology (involving records in organic tissue: wood), the size of increments is an important datum. However, to a much greater extent than in dendrochronology, geochemical time-series (e.g. of stable-isotopic composition or trace-element concentration) are used in sclerochronology, a reflection of the relative immunity of mineral materials from post-mortem chemical alteration. The time-series data facilitate both measurement of elapsed time and identification of environmental changes during the ontogeny/astogeny of the individual/colony concerned. Dependent on the taxon involved and the techniques used, both the chronological precision and the range of environmental parameters documented may be much greater than from dendrochronological data (e.g. Richardson, 2001; Schöne et al., 2002; Schöne and Surge, 2005; Hallmann et al. 2009).

There have been numerous studies of marine environmental conditions involving time-series of growth-increment size and stable-isotope ratios ($^{18}O/^{16}O$, $^{13}C/^{12}C$) from bivalve molluscs (e.g. Richardson, 2001; Schöne and Surge, 2005). Here we review and substantially supplement such data for modern examples of the Queen Scallop, *Aequipecten opercularis* (Fig. 1), discussing what environmental variables may be reflected therein. We then undertake a similar exercise

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