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Palaeogeography, Palaeoclimatology, Palaeoecology 228 (2005) 43–57
PALAEO
www.elsevier.com/locate/palaeo

Freshwater bivalves tell of past climates: But how clearly do shells from polluted rivers speak?

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Received 5 September 2004; accepted 24 March 2005

Abstract

Freshwater bivalves, *Margaritifera margaritifera* (Linnaeus) and *Unio crassus* (Philipsson), from rivers in Sweden (79 specimens) and England (one specimen) were used to study the effects of human-induced pollution on shell growth (Table 1). We analyzed variations in annual and daily shell growth rates of 80 specimens from unpolluted and polluted (pH < 5, oxygen depletion and eutrophication) localities. 35% of the variability in annual growth of shells from unpolluted rivers is explained by ambient temperature during June through August. Daily shell growth also co-varies with the temperature during the growth season (approximately April–October). Long-term trends in temperature and growth compare well to each other. A weak correlation was also found for shell growth and the summer North Atlantic Oscillation (NAO) index. However, all of these environmental signals are obscured in specimens from polluted settings. In settings with high human impact, shell growth does not co-vary with summer temperatures or the NAO. Results of our study suggest a judicious sampling strategy when shells are used for climate reconstructions.

Keywords: Temperature; Sclerochronology; River; Acidification; Eutrophication; Climate proxy

1. Introduction

Shells of freshwater bivalves from mid- to high latitudes provide long, uninterrupted, seasonally to inter-annually resolved archives of continental paleoclimate. Such information can complement climate proxy data derived from tree–rings (e.g., Schweingruber et al., 1991; Grudd et al., 2002; Linderholm et al., 2003) and stalagmites (e.g., McDermott et al., 1999; Frisia et al., 2003; Niggemann et al., 2003). Like bivalve mollusks from marine settings (e.g., Pannella and MacClintock, 1968; Clark, 1975; Jones et al., 1989), freshwater mussels show the following shell growth characteristics: (1) They sensitively record ambient environmental conditions during growth as

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doi:10.1016/j.palaeo.2005.03.050

variable increment widths in their shells (Bauer, 1992; Dunca and Mutvei, 2001). In particular, changes in summer (June–August) air temperature can be inferred from variations of shell growth rates (e.g., Mutvei et al., 1996; Schöne et al., 2004). Faster shell growth occurs during warmer temperatures and growth may cease below certain temperatures. For example, the shell growth of freshwater bivalves from Sweden is limited to temperatures above 5 °C. In southern Sweden, shell growth starts in May and ends in October/November (Dunca and Mutvei, 2001). (2) An unrivaled temporal resolution enables precise calendar dating of each shell portion. Freshwater bivalves grow by periodic accretion of calcium carbonate and produce distinct annual (Hendelberg, 1961; Mutvei et al., 1994; Hastie et al., 2000) and daily growth increments (Dunca and Mutvei, 2001); (3) In addition, some freshwater bivalves have an extremely long life span. Some species reach ontogenetic ages of 100 (Bauer, 1992; Bauer and Wächtler, 2001) and up to 280 years (Mutvei and Westermark, 2001). Growth patterns of shells of extant and subfossil bivalves with overlapping life spans can be strung together to form long master chronologies spanning many mollusk generations (e.g., Jones et al., 1989; Marchitto et al., 2000) thereby enabling multi-centennial reconstructions of environmental conditions and past climate variability.

In the context of the development of sclerochronological techniques, the reliability of environmental reconstructions based on variable growth rates of bivalve shells has rarely been addressed, and rules for judicious sampling have not been formulated. In this regard, it is important that the effects of anthropogenic environmental change and shell growth be determined. For example, recent dendrochronological studies demonstrate that wood density became increasingly insensitive to temperature forcing during the late 20th century (Briffa et al., 1998a,b). Annual changes in the density of latewood are considered to provide an excellent proxy for summer air temperature at the site where the trees grew (Schweingruber et al., 1991). During the last decades, however, wood density and summer air temperature have diverged. Although the causes for this divergence remain unknown, it is hypothesized that increased levels of human-induced climate change such as rising levels of atmospheric CO_2 and NO_x, pollution or UV radiation (Briffa et al., 1998a,b) might have exerted some influence on the wood formation. Our concern is that changes in water quality may affect shell growth.

Here, we apply sclerochronological (growth rate analytical) methods to determine if the shell growth of freshwater bivalves is affected by human-induced environmental disturbances. We question whether specimens from polluted settings can be used for climate reconstructions. We also question whether freshwater shells can monitor and track anthropogenically induced environmental hazards. Furthermore, sampling strategies are suggested for further environmental studies using freshwater bivalves. Results of the present study can be used to improve environmental and climate reconstructions based on shells of freshwater bivalves.

2. Material and methods

Eighty specimens of the freshwater pearl mussel, *Margaritifera margaritifera* (Linnaeus) and one specimen of *Unio crassus* (Philipsson) were collected alive from eight different rivers across Sweden between 1930 (collections stored in the Swedish Museum of Natural History, Stockholm) and 1997 (Fig. 1; Table 1). In addition, we used one specimen collected in 2002 from Borrans Beck, Lake District, England (same latitude, 56°N, as Vramsån). The shells lived in water depths of less than 1 m. Two of the Swedish rivers, the River Slereboån and the River Kvarnbäcken, were affected by human-induced environmental perturbation — in particular during the 1970s — by acid rain that lowered the pH of the water. In the following we refer to the two rivers with strong human impact as ‘polluted’ settings, and to the remaining seven rivers as ‘unpolluted’. As part of mitigation projects since the early 1980s liming was used in both of the polluted rivers to address acidification, and fertilization was used in the in the Kvarnbäcken for the stimulation of the biological activity (Mutvei et al., 1996).

2.1. Sample preparation

One valve of each specimen was cut from the umbo to the ventral margin along the axis of minimum growth (i.e. perpendicular to the winter lines;