**CSIRO** PUBLISHING

www.publish.csiro.au/journals/mfr *Marine and Freshwater Research*, 2006, **57**, 591–599

# Constructing long-term proxy series for aquatic environments with absolute dating control using a sclerochronological approach: introduction and advanced applications

*Samuli Helama*[A,D,E], *Bernd R. Schöne*[A], *Bryan A. Black*[B] *and Elena Dunca*[C]

[A]Institute for Geology and Palaeontology, INCREMENTS Research Group, Johann Wolfgang Goethe University, 60325 Frankfurt am Main, Germany.
[B]Hatfield Marine Science Center, Oregon State University, Newport, OR 97365, USA.
[C]Swedish Museum of Natural History Stockholm, Dept. of Paleozoology, Box 50007, 10405 Stockholm, Sweden.
[D]Present address: Department of Geology, PO Box 64, 00014 University of Helsinki, Finland.
[E]Corresponding author. Email: samuli.helama@helsinki.fi

*Abstract.* The possibility of applying absolute dating techniques to annual growth increments from the hard parts of aquatic animals was examined. This was done using the theory of cross-dating, which was adopted from dendrochronological principles. Using two mollusc species as examples, the practical issues of the method were demonstrated. Empirical data were used to evaluate the different time series analysis techniques as follows. Biological growth trends were first captured from original time series using cubic splines. Dimensionless growth indices were obtained by extracting the observed growth values from the values of spline curves as ratios. The common growth signal among the index series was quantified visually and statistically. In statistical analysis, correlations between all possible pairs of indexed sample series and, alternatively, between sample series and master chronology (the average of all other remaining time series) were calculated. It was demonstrated that sample–master correlations were consistently higher than sample–sample correlations. Sclerochronologically cross-dated time series were proved to provide absolute dating of high-resolution proxy records that assessed environmental change in marine and freshwater settings. The wider applicability of the associated techniques is discussed, and it is suggested that use of the term 'sclerochronology' be restricted to refer only to material or studies for which careful cross-dating has been successfully applied.

*Extra keywords*: *Arctica islandica*, dendrochronology, *Margaritifera margaritifera*, proxy records, sclerochronology.

## Introduction

Periodic growth increments occur in a wide taxonomic range of organisms representing terrestrial, freshwater and marine environments. Growth-increment properties are strongly dependent on environmental conditions at the time of formation, and consequently have been widely used to reconstruct past environmental variability and change. By far the most well known and widely studied growth-increment data are tree rings, which have been used to reconstruct climate and forest dynamics over thousands of years at spatial scales ranging from local to hemispheric. Over the past decade, growth increments formed in skeletons of aquatic organisms such as molluscs, corals, brachiopods and fish have gained considerable attention (Clark 1974; Hudson *et al*. 1976; Lutz and Rhoads 1980; Jones 1983; Begg *et al*. 2005; Black *et al*. 2005; Campana 2005; Schöne and Surge 2005). These organisms occur from the tropics to the arctic and from the deep sea to shallow coastal waters, representing an immense diversity of marine and freshwater ecosystems. Their growth increments could provide data on several climatic and ecological processes in remote and relatively unexplored locations. Shell growth increments have been used as proxies of various aquatic variables, such as temperature (Davenport 1938; Kennish and Olsson 1975; Goodwin *et al*. 2001), salinity (Navarro 1988; Marsden and Pilkington 1995) and food availability (Ansell 1968; Schöne *et al*. 2003). Yet overall, the study of growth increments in aquatic organisms, broadly referred to as sclerochronology, has been largely neglected in comparison with its terrestrial counterpart – dendrochronology. Nevertheless, sclerochronology shows enormous potential for addressing issues in aquatic environments that are analogous to those addressed in terrestrial environments by dendrochronology.

One of the most serious limitations to sclerochronology is that protocols for assigning the correct calendar year to each growth increment have not been well developed. In terrestrial

 10.1071/MF05176 1323-1650/06/060591