



Food for thought: Mathematical approaches for the conversion of high-resolution sclerochronological oxygen isotope records into sub-annually resolved time series



Peter Müller^{a,*}, Marc H. Taylor^a, André Klicpera^a, Henry C. Wu^b, Julien Michel^c, Hildegard Westphal^{a,d}

^a Leibniz Center for Tropical Marine Ecology (ZMT), Bremen, Germany

^b MARUM, Center for Marine Environmental Sciences, University of Bremen, Germany

^c Department for Earth Sciences, VU University Amsterdam, The Netherlands

^d Department of Geosciences, University of Bremen, Germany

ARTICLE INFO

Article history:

Received 28 April 2015

Received in revised form 4 September 2015

Accepted 15 September 2015

Keywords:

Sclerochronology

Bivalve

Otolith

Von Bertalanffy growth function

Growth model

Temporal alignment

ABSTRACT

Oxygen isotope ($\delta^{18}\text{O}$) records of incrementally banded marine calcifiers provide high-resolution information about modern and past environmental conditions. However, given their biological origin, these records are often distorted by ontogenetic and seasonal growth pattern. To evaluate their reliability, many studies correlate skeletal $\delta^{18}\text{O}$ records with instrumentally measured time series of environmental conditions using a variety of methods to recalculate their temporal framework. Lacking consistency and a limited traceability of many temporal alignment methods underline the need for standardized and flexible method for the temporal alignment of sclerochronological records. Here, two methods for the temporal alignment of sclerochronological data and their application on measured oxygen isotope signatures of a fish otolith and a marine bivalve shell are presented and compared. The first method is a flexible approach using a linear interpolation between carefully selected temporal reference points for recalculating ontogenetic growth effects with an optional extension accounting for seasonal growth oscillations. The second approach uses the seasonally-oscillating Von Bertalanffy growth function parameterized based on the oxygen isotope record to reconstruct the underlying growth model and reconstruct thereby its temporal framework. Using these methods, we re-align $\delta^{18}\text{O}$ -based water temperature records of a *Carliarius heudelotii* otolith and a *Venus crebrisulca* shell with measured sea surface temperature time series and compare the resulting correlation as well as the different underlying growth models. Our results show that both methods represent useful tools for the temporal alignment of sclerochronological records. However, underlying growth models strongly differ depending on the temporal alignment method and the parameters used for the reconstruction of the temporal framework. This underlines the importance of a careful selection of a particular alignment method depending on the complexity of distortion due to seasonal and ontogenetic growth trajectories. Moreover, we show that both organisms represent reliable paleoenvironmental archives providing sub-seasonally resolved water temperature records.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The analysis of incrementally banded calcareous structures of aquatic organisms (e.g. bivalve shells, corals, fish otoliths and others) has become a valuable tool for studying modern as well as ancient climate variability (Andrus, 2011; Schöne and Gillikin, 2013). Using sclerochronological approaches, ontogenetic proxy records such as oxygen isotopes ($\delta^{18}\text{O}$) provide high-resolution (sub-daily to sub-seasonal) records of environmental conditions covering time intervals ranging

from several months to millennia (Schöne et al., 2004, 2005a; Surge and Walker, 2005; Hallmann et al., 2008; Lavaud et al., 2013).

To evaluate the reliability of such paleoenvironmental archives, ontogenetic $\delta^{18}\text{O}$ records of modern organisms are often compared to and regressed against instrumentally measured environmental variables. However, in order to align these proxy records with instrumental time series, a well-constrained temporal framework throughout the sclerochronological records is required. Besides commonly observed annual growth bands, micro-increments induced by daily or tidal cycles can provide such a temporal framework enabling the conversion of ontogenetic $\delta^{18}\text{O}$ records into high-resolution time series (Schöne et al., 2005b, 2005c; Lavaud et al., 2013). The use of micro-increments for the temporal alignment of sclerochronological data certainly represents the most reliable reconstruction of ontogenetic growth pattern and should be used whenever micro-increments are observable. However,

* Corresponding author at: Leibniz Center for Tropical Marine Ecology (ZMT), Fahrenheitstraße 6, 28359 Bremen, Germany.

E-mail address: peter.mueller@zmt-bremen.de (P. Müller).

a large number of marine organisms do not provide such well-defined and continuous records of apparent micro-increments. Moreover, seasonal growth variability with growth hiatuses or episodes of enhanced or reduced growth distorts the chronological formation of growth increments in almost every aquatic organism from coastal settings to abyssal depths (Goodwin et al., 2003), complicating the interpretation of measured ontogenetic proxy records in many cases. This distortion is usually further complicated by ontogenetically decreasing growth rates impeding a straightforward conversion of isotope records into a time series.

Many studies on organisms which are lacking apparent micro-increments use a variety of approaches to compensate for these issues such as comparing measured $\delta^{18}\text{O}_{\text{Carbonate}}$ data with modeled theoretical $\delta^{18}\text{O}_{\text{Carbonate}}$ data based on measured environmental conditions (e.g. Surge et al., 2001; Freitas et al., 2006), applying linear interpolations within the proxy data (e.g., Maier and Titschack, 2010; Welsh et al., 2011), graphic manipulation (stretching or compression) (e.g., Dettman et al., 1999; Versteegh et al., 2012; Bougeois et al., 2014), computation with special software (e.g., Paillard et al., 1996; Walther and Rowley, 2013), geodesic operations (Nasreddine et al., 2009) or presenting the data without any temporal framework (e.g., Surge and Walker, 2005; Jones et al., 2009; Wang et al., 2013; Gordillo et al., 2015). However, reporting sclerochronological data without any temporal context hampers the direct comparison with measured environmental variables. Other studies using mathematical or graphical approaches often provide little information on important parameters that explain the temporal alignment and impede its replicability. Both aspects clearly underline the need for a flexible and traceable method for temporal alignments when micro-increments are not available.

In response to these shortcomings, we developed two different mathematical approaches for the replicable temporal alignment of sclerochronological data, which cover a wide range of potential applications. Both methods are based on the assumption that characteristic $\delta^{18}\text{O}_{\text{Carbonate}}$ values throughout the skeletal record can be assigned to corresponding events recorded in the measured environmental variable (e.g. measured $\delta^{18}\text{O}$ maxima and minima and corresponding water temperature minima and maxima, respectively). However, this implies that skeletal structures as well as the sampling technique (e.g. micro milling) provide an adequate spatial (i.e. temporal) resolution to ensure the correct identification of such temporal reference points.

The first method uses a simple linear interpolation based on carefully selected reference points throughout the skeletal record (e.g. $\delta^{18}\text{O}_{\text{Carbonate}}$ maxima/minima) to recalculate the temporal framework. Although linear interpolations have already been used in previous studies, we provide a ubiquitous applicable equation enabling a standardized notation for documenting the temporal alignment of sclerochronological data. This approach allows using an arbitrary number of reference points per year and enables the introduction of growth cessations into the reconstructed time series. The introduction of growth cessations is of particular importance as many calcifying organisms show considerable slowdowns or even growth cessation beyond the upper and/or lower thermal limits (Goodwin et al., 2003). Moreover, we developed an optional extension for the linear interpolation approach which allows the consideration of seasonal growth oscillations throughout the sclerochronological record.

The second method represents the application of an extended version of the Von Bertalanffy growth function (VBGF; von Bertalanffy, 1934), published by Somers (1988), which models ontogenetic growth trends including a sinusoidal oscillating term accounting for seasonal growth variations. The application of the common VBGF as well as the seasonally-oscillating VBGF (soVBGF) on ontogenetic sclerochronological records is theoretically possible since the incremental growth of calcified structures mostly corresponds to overall size of an organism (for fish otoliths see e.g. Casseleman, 1990) or can directly be related to the same parameter (e.g. shell height in bivalves, see Cloern

and Nichols, 1978). By using the distance between selected reference points throughout a sclerochronological record (e.g. local $\delta^{18}\text{O}_{\text{Carbonate}}$ maxima/minima), and their corresponding timing (e.g. seasonal temperature minima/maxima, respectively), one has all the information needed for an iterative fitting of the soVBGF to individual proxy records.

In this study, we explore the potential of both approaches for the temporal alignment using measured ontogenetic otolith and bivalve shell $\delta^{18}\text{O}$ signatures and subsequently calculated water temperature records. The high-resolution $\delta^{18}\text{O}_{\text{Carbonate}}$ records were measured from one modern Smoothmouth sea catfish otolith (*Carliarius heudelotii*, Valenciennes 1840) and one modern marine bivalve (*Venus crebrisulca*, Lamarck, 1818), sampled on the Banc d'Arguin, Mauritania, NW Africa in November 2011 and March 2008, respectively. The resulting temporal alignments and the underlying growth models are also compared with the most commonly applied temporal alignment method using predicted $\delta^{18}\text{O}_{\text{Carbonate}}$ time series for the conversion of skeletal records into time series.

Supplemental material includes calculations and raw data of all examples presented in this study and a script for the soVBGF approach based on the R statistical computing language (R Development Core Team, 2013) and are available online (Müller et al., 2015).

2. Material and methods

2.1. *C. heudelotii* and *V. crebrisulca* sampling and preparation

The *C. heudelotii* otolith was removed from an individual caught in November 2011 in the northernmost part of the Banc d'Arguin (central Baie du Lévrier, water depth <20 m), Mauritania, NW Africa. *C. heudelotii* is classified as demersal marine–estuarine (ME) species preferring coastal and estuarine environments but reproducing under marine conditions and occurs along the entire West-African coast from Mauritania to Angola (Taylor, 1986; Schneider, 1990).

The *V. crebrisulca* individual used for this study was collected alive in February 2008 on the western central Banc d'Arguin, (20.17°N,

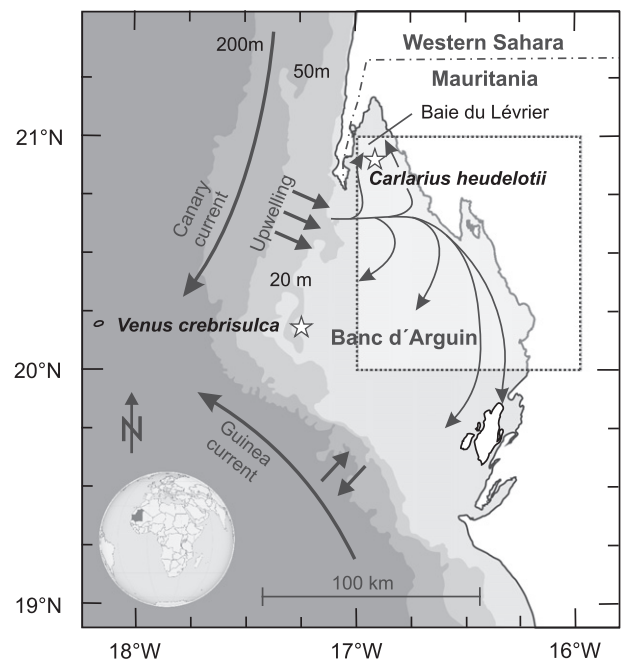


Fig. 1. The Banc d'Arguin in northern Mauritania. Sampling sites of the *Venus crebrisulca* and *Carliarius heudelotii* individuals are indicated by white stars. Area covered by SST data is indicated by the dotted rectangle.

Download English Version:

<https://daneshyari.com/en/article/6349585>

Download Persian Version:

<https://daneshyari.com/article/6349585>

[Daneshyari.com](https://daneshyari.com)