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Sclerochronology and Growth of the Bivalve Mollusks *Chione* (*Chionista*) *fluctifraga* and *C.* (*Chionista*) *cortezi* in the Northern Gulf of California, Mexico

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Abstract. Sclerochronology and analysis of oxygen isotopes reveal the age, growth rate, and growth patterns of *Chione* (*Chionista*) *cortezi* and *Chione* (*Chionista*) *fluctifraga*. *Chione* (*C.*) *cortezi* grows more quickly than *Chione* (*C.*) *fluctifraga,* but has a shorter life span (8 years versus 16 years). Microgrowth increments form with tidal periodicity, and their width is mostly influenced by temperature. Microincrement patterns reveal that maximum growth occurs from April to June and again in October. Growth is reduced during the hottest part of the summer and the coldest part of the winter. Growth breaks often occur in December/January and August. Timing of shell growth and environmental conditions were verified by high-resolution oxygen isotope measurements.

INTRODUCTION

Bivalve mollusks of the genus *Chione* Megerle von Mühlfeld, 1811, inhabit many coastal areas around the world (Moore 1969:N686). Although they are often commercially exploited, little is known about their life span, overall growth patterns, and growth rates. The effect of temperature on the growth rate of *Chione* species is not well understood. Such information is important for the management of shellfish resources and mariculture.

Early attempts to determine the age and growth rate of mollusks used shell-weight or size-frequency analysis. The disadvantages of these methods have been reviewed by Berta (1976) namely: (1) the exact age of the youngest year class remains unknown; (2) year classes can be absent; and (3) size or weight ranges of specimens of different year classes can overlap due to differences in environmental conditions during their life. The major concentric rings on the external shell surfaces of mollusks have often been interpreted as annual growth patterns. However, they cannot always be distinguished unequivocally because rings may also be caused by non-seasonal disturbances. In addition, annual growth rings are crowded at the ventral margin in older specimens and make counting and interpretation difficult (see Zolotarev, 1980). Other researchers (e.g., Jones et al., 1978; MacDonald & Thomas, 1980) suggested that the most reliable method is to count the annual growth increments (first order increments or "1st-order layer" sensu Barker, 1964) preserved in radial cross-sections of the shells.

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Since Wells's (1963) pioneering study, in which the microgrowth increments (higher order increments) of corals were used to infer the number of days in a Devonian year, many articles have dealt with the microgrowth increments of bivalve mollusks and other animals (for a review see Rhoads & Lutz, 1980 and references therein). This type of study has been termed "sclerochronology" (Buddemeier, 1975; Hudson et al., 1976).

Sclerochronology can be used to elucidate differences in growth rates and life histories of morphologically similar species. Sclerochronological methods can be applied to shells of fossil (Pannella 1976; Schöne, 1999) as well as living specimens. Organisms that produce accretionary hardparts serve as environmental recorders during their lives. Variation in growth rates and repeating growth structures have been interpreted to reflect endogenous rhythms, physiological periodicity, or environmental cycles. Varying widths of growth increments have also been attributed to random ecological fluctuations (e.g., Kennish & Olsson, 1975; Peterson, 1983). The stable isotope composition of growth layers is now being used in many paleobiological and paleoenvironmental studies (e.g., Turekian et al., 1982; Williams et al., 1982; Roux et al., 1990; Kirby et al., 1998; Jones & Gould, 1999); and a few studies address the chemical content of the growth increments (e.g., Mutvei et al., 1994).

Here we present the results of stable isotope and sclerochronological investigations on the bivalve mollusks *Chione* (*Chionista*) *fluctifraga* (Sowerby, 1853) and *Chione* (*Chionista*) *cortezi* (Carpenter, 1864, ex Sloat MS) from the intertidal zone of the northern Gulf of California, Mexico. We describe inter- and intra-annual growth patterns and growth rates and interpret them in order to