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Environmental controls on shell growth rates and $\delta^{18}O$ of the shallow-marine bivalve mollusk *Phacosoma japonicum* in Japan

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Abstract Microgrowth patterns and the oxygen isotope composition of juvenile, shallow-marine bivalve mollusk shells of *Phacosoma japonicum* (Reeve) in Japan were analyzed and cross-calibrated with environmental parameters. Mark-and-recovery experiments indicate that a pair of two microgrowth lines and two microgrowth increments is produced every lunar day. This finding makes it possible to assign exact calendar dates to each portion of the shell. Average daily growth rates decrease by 61% from age two to three and 55% from age three to four. The length of the growing season and the growth rate are mainly controlled by temperature: shell growth ceases below 14.2°C (age two) and 16.8°C (age four) and is most rapid between 24.6°C and 27.2°C. Based on local temperature cycles, the growing season is longest in Seto Inland Sea, central Honshu (from May to November) and shortest at Hakodate Bay, North Japan (from June to October). The annual oxygen isotope profiles of the shells reflect the temperature cycle and the varying amounts of freshwater added to the seawater by precipitation. The most negative $\delta^{18}O$ values of –3.15‰ occur during the rainy season, i.e. during the monsoon and typhoon seasons. Growth rates are only slightly affected by salinity changes. Strongly reduced growth rates during the second half of the year at Seto Inland Sea and to a lesser extent at Tokyo Bay are explained by nutrient deprivation. Our study provides the basis for the use of *P. japonicum* in high-resolution ecological studies and environmental reconstructions.

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Introduction

Shallow-marine bivalve mollusks contain high-resolution records of environmental change in their shells. The growth conditions are recorded, for example, in variations of the stable oxygen isotope composition across the shells (e.g. Epstein et al. 1953; Grossman and Ku 1986; Kennedy et al. 2001) and in variable shell growth rates of extant (e.g. Williams et al. 1982; Weidman et al. 1994; Marchitto et al. 2000; Goodwin et al. 2001; Schöne 2003) and fossil bivalves (Steuber 1996; Kirby et al. 1998). High-resolution environmental data contribute to the understanding of life-history traits (Sato 1999a), biogeographic distribution of species (Hall et al. 1974), and community structures, and can be important for mariculture and the management of shellfish resources (Ansell 1962, 1968; Menzel and Sims 1964). Furthermore, high-resolution data derived from shallow-marine bivalve shells can assist in developing more precise climate models. Up to now, little information has been available on ancient seasonal and sub-seasonal environmental variability, especially in extra-tropical, shallow marine settings (Schöne et al. 2002b). More advanced climate models are essential to reconstruct past climates, to assess the role of humans in global climate change and to predict the future evolution of the atmosphere's and the oceans' circulation and thermodynamics (Manabe and Stouffer 1988; Kumar et al. 1996; Derome et al. 2001; Liu et al. 2002).