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Application of carbonate-clumped thermometry in bivalve shells as environmental stress indicator

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Carbonate-clumped thermometry has demonstrated efficacy as a potent tool in inferring palaeoclimate temperature. Its application lies beyond deducing temperature; it has recently been used to detect “out-of-equilibrium” precipitation processes, particularly in inorganic carbonate shells, which are biologically mediated and susceptible to such “vital effects”. In the present study, we have examined modern-day freshwater bivalves belonging to the family *Unionidae* (from the Ganga river alluvial bank) and experimented with carbonate-clumped thermometry on carbonate powder derived from the last growth line of the shells. Our sampling method ensures the isotopic analysis of the recent precipitation by the bivalves to allow comparison with the observed ambient geochemical signature. Reports suggest that physiological control in the isotopic fractionations in bivalve shells can influence shell geochemistry, as reflected in the clumped isotope values (Δ_{47}). In two years of sampling (2018 and 2020), we observe the average Δ_{47} = 0.709‰ and 0.750‰, respectively. The difference in Δ_{47} is 0.04‰ defines the average clumped isotope-based temperature estimates of 23.7°C for 2018 and 14.5°C for 2020. Similarly, the difference in average δ^{13}Cshell values for the 2018 and 2020 samples is 1.32‰. However, the average $\delta^{18}O_{shell}$ varies minimally. A significant factor that can be attributed to the resultant isotopic variation is the change in river water chemistry during these two different years, as 2020 was a year of COVID lockdown with strict protocols implemented in the otherwise polluted Ganga River region. 2020 marked the period of reduced anthropogenic activity as observed from satellite data. We employ the Landsat-8, level-2 data from this region to study spatial and temporal variations of the Ganga River water temperature and other chemical attributes, further confirming our hypothesis. High Chlorophyll-a concentrations (an indicator of phytoplankton concentration) in this region are due to reduced anthropogenic activity and are well reflected in the $\delta^{13}C_{shell}$ composition in our analysis. Similarly, the discrepancy in Δ_{47} is regulated by the disequilibrium growth behaviour. This new method can trace the environmental stress from the clumped isotope analysis of bivalve shells and use them as a biomonitoring tool in susceptible flow systems contaminated with industrial effluent or anthropogenic discharge.