Carbon and oxygen isotope analysis of modern freshwater mollusk shells: applications for climate reconstruction

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Geochemistry of Natural Waters

Introduction

Mollusks are useful as paleoclimate indicators because their shell growth rate is primarily controlled by water temperature. As they precipitate their shells in layers of coeval calcite and aragonite, light bands develop during the summer and dark bands in the winter (Jones and Quitmyer, 1996), allowing for up to seasonal-precision sampling of shell isotopic signatures and thus high-resolution climate reconstruction: the $\delta^{18}O$ signature of mollusk growth bands reflects water temperature and geochemistry, because mollusks frequently precipitate their shells in isotopic equilibrium with the surrounding water (Gillikin et al., 2005). Additionally, marine mollusk shells have been shown to record the $\delta^{13}C$ signatures of dissolved inorganic carbon (DIC) in the surrounding water (Dettman et al., 1999), and it is possible that freshwater mollusks behave similarly.

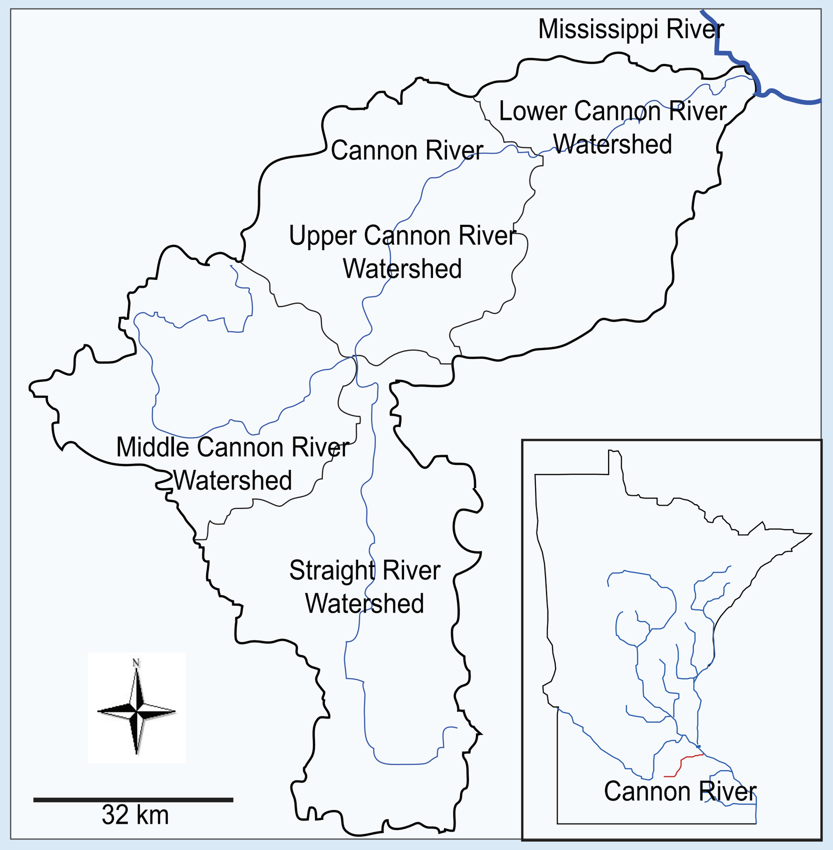


Figure 1. The Cannon River is located in southeastern Minnesota. It is 120 miles long, running from Shields Lake to the Mississippi River, and includes residential, commercial, agricultural and undeveloped land.

In this study, we analyze two species of freshwater mollusk from the Cannon River: *Lampsilis* sp. and *Potamilns alatus*. The Cannon River has experienced natural climatic fluctuations over the last few hundred years as well as environmental change due to industrial and commercial development (see Fig. 1). Although the mollusks analyzed in this study are of unknown age, we expected that shell isotopic signatures would record both seasonal and annual environmental variability.

Results

The $\delta^{13}C$ and $\delta^{18}O$ signatures of bulk samples from both the *Lampsilis* and *Potamilns* shells were generally different from the signatures of sampled locations.

-*Lampsilis* bulk samples had significantly different $\delta^{13}C$ signatures from individual samples (p=0.04) and $\delta^{18}O$ signatures tended to be different (p=0.12).

-For both the small and large *Potamilns* valves, bulk sample $\delta^{13}C$ values showed significant variation from sampled locations (p<0.01 and p=0.03, respectively). However, bulk sample $\delta^{18}O$ signatures showed no difference from the small valve *Potamilns* samples (p=0.92), but were significantly different from large valve *Potamilns* samples (p=0.10).

-$\delta^{13}C$ and $\delta^{18}O$ signatures were significantly different between samples from the small and large *Potamilns* valves (p<0.01 and p=0.06).

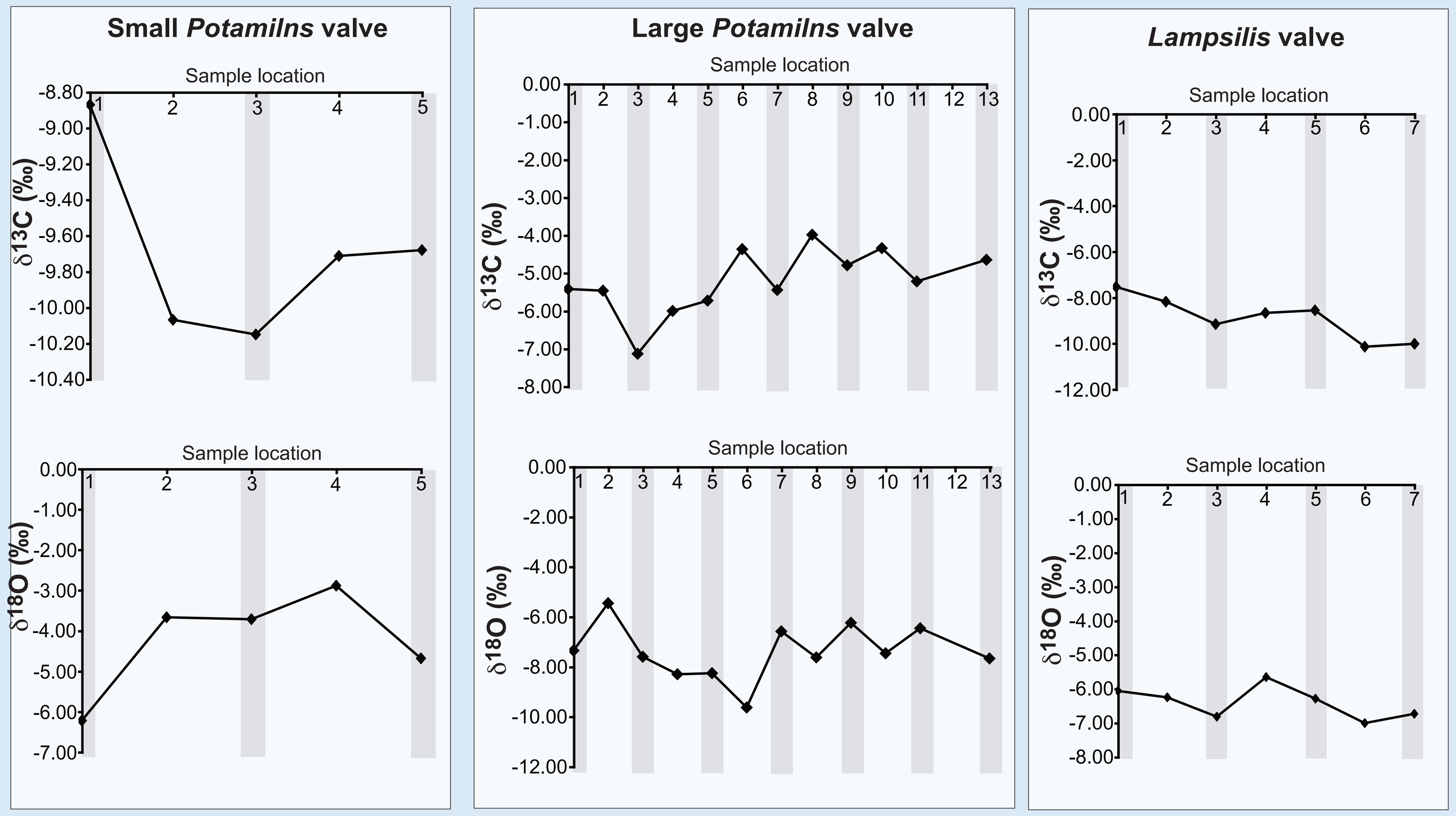
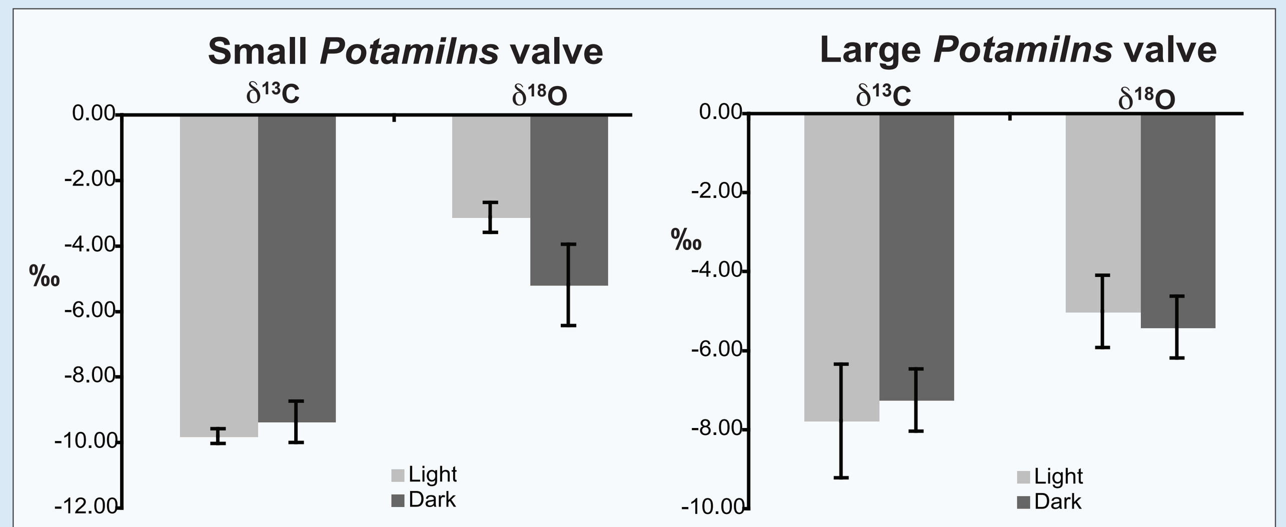


Figure 3. $\delta^{18}O$ and $\delta^{13}C$ signatures of growth bands from the shells sampled; sample numbers begin at the youngest part of the shells and increase towards its edge and gray lines indcate dark bands. $\delta^{18}O$ signatures from growth bands in the large and small *Potamilns* valves show variability both between light and dark bands and over multiple bands, with the long-term variability having a greater magnitude. Trends in $\delta^{13}C$ signatures mimic $\delta^{18}O$ variability, though to a lesser extent. The *Lampsilis* shell shows almost no variability between individual bands, and little variability across multiple bands for either $\delta^{18}O$ or $\delta^{13}C$.



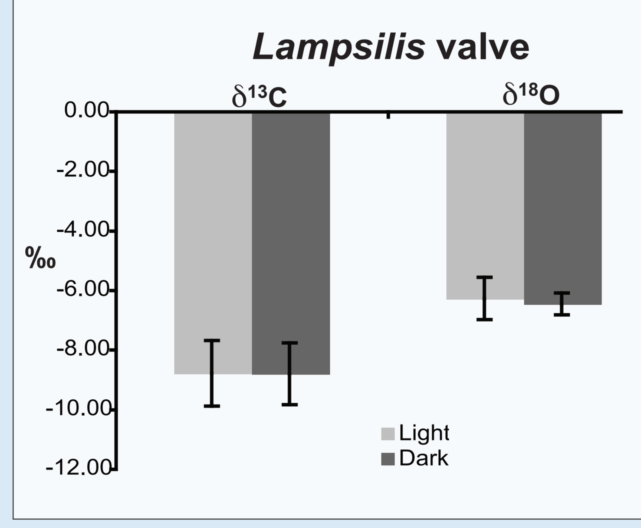


Figure 4. Variation in $\delta^{18}O$ and $\delta^{13}C$ signatures between light and dark growth bands. The small *Potamilns* valve shows a significant difference in $\delta^{18}O$ between light and dark bands (p=0.04), while neither the large valve nor the *Lampsilis* shell do (p=0.37 and 0.66). Differences in $\delta^{13}C$ signatures are not significant in any of the shells (p=0.31, 0.36, and 0.98, respectively).

Conclusions

Assuming that variability in $\delta^{18}O$ signatures reflects seasonal changes in water temperature, with a cyclical variation between ^{18}O-depletion (winter) and ^{18}O-enrichment (summer), both *Potamilns* valves showed greater variability on an inter-annual than a seasonal timescale (Fig. 3). *Lampsilis* shell $\delta^{18}O$ showed less variation on either timescale, suggesting that this species records temperature with less accuracy. Comparison of sampled areas with bulk samples showed that the mollusks had experienced a wider range of temperatures over their lifetimes than indicated by the areas of the shells sampled.

In general, growth band $\delta^{18}O$ signatures record high-resolution temperature variation, and suggest that water temperatures during the mollusk's life did not vary within a consistent seasonal range but were subject to larger-scale trends. With no significant difference in $\delta^{13}C$ between light and dark bands in any of the shells studied, our results support the consensus that growth band $\delta^{13}C$ in freshwater mollusks does not correlate to specific paleoenvironmental trends (cf. Geist et al., 2005). While we cannot estimate historical Cannon River temperatures from our data, it is clear that Cannon River mollusks, particularly *Potamilns alatus*, are sensitive indicators of paleotemperature, recording temperature variations between seasons and over multiple years through growth band $\delta^{18}O$ signatures.

Methods

Shell slices from *Potamilns alatus* and *Lampsilis* sp. were mounted as thick sections (~300mm) and samples were drilled along growth bands using a Merchantek Leica GZ6 MicroMill (see Fig. 2). A hand-drill was used to collect bulk samples from the surface of both shell sections (the *Potamilns* bulk sample included material from both small and large valves of one shell). Samples were heated at 300º C for one hour in order to remove organic material, and then analyzed with a Finnigan MAT 252 dual inlet mass spectrometer at the University of Utah in Salt Lake City, using the UU - Carrara (> 140 mesh) carbonate standard for calibration.

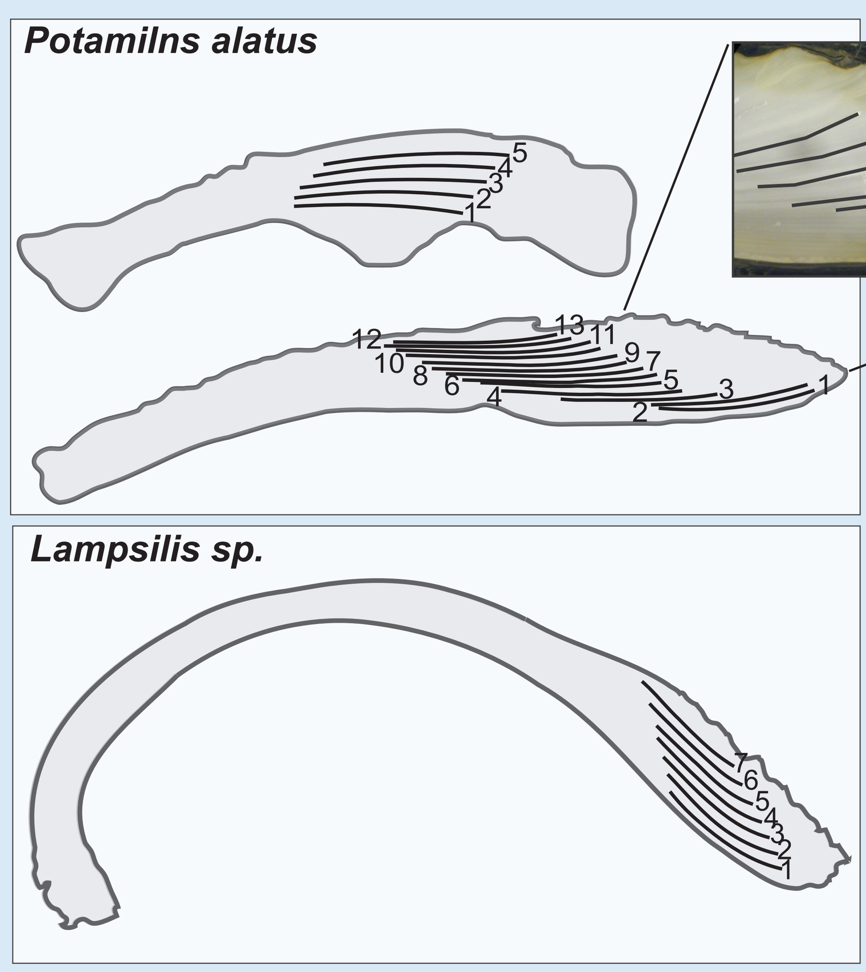


Figure 2. Sample locations on the *Potamilns* and *Lampsilis* shells. Both the small and large valves on the *Potamilns* shell were sampled.

Shells were collected in the summer of 1993 from the Cannon River near the Faribault Dam; shell condition suggested that the mollusks died in the late 1980s.

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References

Brey, T., and A. Mackensen. 1997. Stable isotopes prove shell growth bands in the Antarctic bivalve Laternula elliptica to be formed annually. *Polar Biology* 17:465-468.

Dettman, D.L., A. K. Reische, and K. C. Lohmann. Controls on the stable isotope composition of seasonal growth bands in aragonitic fresh-water bivalves (unionidae). *Geochimica Et Cosmochimica Acta* 53: 1049-1057.

Geist, J., K. Auerswald, A. Boom. 2005. Stable carbon isotopes in freshwater mussel shells: Environmental record or marker for metabolic activity? *Geochimica et Cosmochimica Acta* 69: 3545-3554.

Gillikin, D.P., F. De Ridder, H. Ulens, M. Elskens, E. Keppens, W. Baeyens, and F. Dehairs. 2005. Assessing the reproducibility and reliability of estuarine bivalve shells (Saxidomus giganteus) for sea surface temperature reconstruction: Implications for paleoclimate studies. *Palaeogeography Palaeoclimatology Palaeoecology* 228: 70-85.

Goodwin, D. H., D. L. Dettman, K. W. Flessa, and B. R. Schoene. 2003. *Estuarine, Coastal and Shelf Science* 58: 715-726.

Jones, D. S., and I. R. Quitmyer. 1996. Marking time with bivalve shells: oxygen isotopes and season of annual increment formation. *Palaeos* 11: 340-346.

Jones, D. S., I. R. Quitmyer, and C. F. T. Andrus. 2005. *Palaeogeography, Palaeoclimatology, Palaeoecology* 228: 96-108.