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Oxygen and Carbon Isotopes in Modern and Historic Mussels from the Snake River, Idaho, May Show Modern Rise of Corn Production

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Abstract

Stable carbon and oxygen isotope compositions were analyzed from local mussels ranging in age from 0 to 1000 years before the present to identify any trends and seasonal variability in the oxygen and carbon (◇18O and ◇13C values), compare trends and averages in ◇18O and ◇13C across different time periods and species of mussel, and finally use ◇18O to gain insight into how climate conditions might have changed in the past 1000 years. The Western Ridged Mussel (*Gonidea angulate*) and Western Pearlshell Mussel (*Margaritifera falcata*) are two species of freshwater mussels found in the Snake River in southern Idaho. Both species seasonally produce a calcium carbonate shell outward as they age. Previous research has shown mussels typically form their shells in isotopic equilibrium with the surrounding water and therefore can be a reliable indicator of environmental conditions such as temperature and seasonality. Outer growth bands were sampled sequentially from mussels dated ~1200 years before present, as well as from modern shells. The powdered samples were analyzed using an isotope ratio mass spectrometer in the Department of Geosciences, Boise State University, to obtain δ18O and δ13C values. Modern shells were found to have an average δ18O value of -16.6‰ (VPDB) and an average δ13C value of -8.8‰ (VPDB). δ18O was nearly constant across the shell, but δ13C increased as the mussel grew. Historic shells had homogeneous δ18O values of -16.4‰ and homogeneous δ13C values of -11.6‰. δ18O values of the two time periods are very similar, suggesting no resolvable changes to climatic conditions using this proxy. Increased δ13C values in modern mussels relative to historic mussels suggest a potentially significant increase of C4 plant contribution to the Snake River. We interpret this enrichment to be due to modern production of corn (a C4 plant) along the Snake River, especially since ~2000 CE.

Oxygen and Carbon Isotopes in Modern and Historic Mussels From the Snake River Idaho, May Show Modern Rise of Corn Production

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Abstract

Stable carbon and oxygen isotope compositions were analyzed from local mussels ranging in age from 0 to 1000 years before the present to identify any trends and seasonal variability in oxygen and carbon ($\delta^{18}O$ and $\delta^{13}C$ values), compare trends and averages in $\delta^{18}O$ and $\delta^{13}C$ across different time periods and species of mussel, and finally use $\delta^{18}O$ to gain insight into how climate conditions might have changed in the past 1000 years.

Modern shells have an average $\delta^{18}O$ value of -16.6‰ (VPDB) and an average $\delta^{13}C$ value of -8.8‰ (VPDB). $\delta^{18}O$ was nearly constant across each shell, but $\delta^{13}C$ increased as the mussel grew. Historic shells had homogeneous $\delta^{18}O$ values of -16.4‰ and homogeneous $\delta^{13}C$ values of -11.6‰. $\delta^{18}O$ values of the two time periods are very similar, suggesting no resolvable changes to climatic conditions using this proxy. Increased $\delta^{13}C$ values in modern mussels relative to historic mussels suggest a potentially significant increase of C_4 plant contribution to the Snake River. We interpret this enrichment to be due to modern production of corn (a C_4 plant) along the Snake River, especially since ~2000 CE.

Introduction + Site Information

- The Snake River is a major river in southern Idaho.
- Western Ridged and Western Pearlshell mussel are two species of mussel that reside in the river. Shells from these mussels were collected representing modern and historic conditions.
- Mussels seasonally produce a calcium carbonate shell outward as they age (see figure 2).
- Shell $\delta^{18}O$ values represent a combination of temperature and local water composition of a mussel's environment (Epstein et al., 1953). Shell $\delta^{13}C$ isotopes represent a combination of the mussel's metabolism and dissolved carbon in the water (Geist et al., 2005).

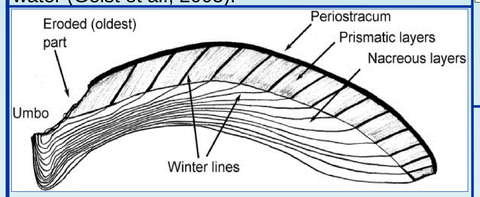

Figure 2: Diagram of a cross section of a mussel shell. Outer prismatic layers were sampled (Image from Geist et al., 2005).

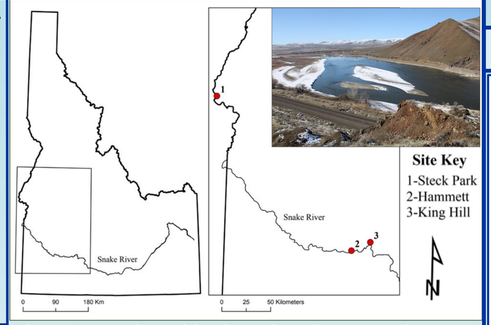

Figure 1: Locations of the three sites where mussel samples were collected. Site 1 is modern, sites 2 and 3 are archaeological sites with ages of ~1200 and ~1300 years before present, respectively. The inset picture is of the Snake near Steck Park

This study aims to:

1. Measure $\delta^{18}O$ and $\delta^{13}C$ values from modern and historic Snake River mussel shells and identify trends and averages in $\delta^{18}O$ and $\delta^{13}C$ values.
2. Use $\delta^{18}O$ to gain insight into how climate might have changed in the past 1000 years.

Basics Of Stable Isotope Geochemistry

- Isotopes are different versions of the same element that have the same number of protons but different numbers of neutrons. Stable isotopes do not decay over time.
- Elements that have stable isotopes typically have a common isotope and a rare isotope.
- The rare and common isotopes have different masses and the ratio of the two (R_{sample}) can be obtained from a mass spectrometer.
- This ratio is then converted into delta (δ) notation comparing said ratio to a standard (see figure 3). VPDB ($R_{standard}$) is the standard for $\delta^{13}C$ and $\delta^{18}O$ used in this study.
- Higher δ13C and δ18O means more ^{13}C and ^{18}O.

$$\delta = \left(\frac{R_{sample}}{R_{standard}} - 1\right) \times 1000$$

Figure 3: Delta notation equation

Sampling Methods

Figure 4: Hand sampling of a mussel shell. (Photo: Robert Welle)

- Excess dirt was removed from the shells by brushing or rinsing with DI water.
- The outer calcite layer of the shells was abraded along growth bands to create powder samples.
- Samples were typically collected in 1.5-2mm intervals, but some were up to 10mm apart.
- Every other sample was weighed out and analyzed using a ThermoFisher Delta V Plus mass spectrometer in the Department of Geosciences.
- $\delta^{18}O$ and $\delta^{13}C$ have analytical uncertainties of ~±0.2‰.

Figure 5: Before and after sampling a mussel (in red boxes).

Results

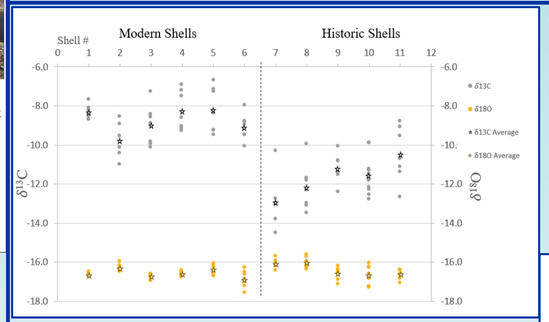

Figure 6 (above): $\delta^{18}O$ and $\delta^{13}C$ values obtained per shell. Modern shells have higher $\delta^{13}C$ values than historic shells. $\delta^{18}O$ values are homogenous.

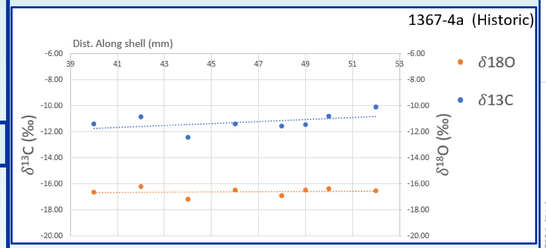

Figure 7 (Above): Isotope values across a historical shell. $\delta^{13}C$ lacks a strong enrichment over time and is more variable than modern shells. $\delta^{18}O$ values are homogenous.

Table 1: $\delta^{18}O$ and $\delta^{13}C$ mean values of modern and historic shells. T-tests show a significant difference in $\delta^{13}C$ values between modern and historic shells. T-tests between the different species show a significant difference in historic shells but none in modern shells.

Statistical Test	$\delta^{13}C$	$\delta^{18}O$
Mean (Modern Shells)	-8.8‰	-16.6‰
Mean (Historic Shells)	-11.6‰	-16.4‰
T-Test (Modern vs Historic)	$1.6x10^{-16}$	$2.2x10^{-2}$
F-Test (Modern vs Historic)	$6.9x10^{-2}$	$4.3x10^{-2}$
T-Test (Modern Species Comparison)	0.16	0.44
T-test (Historic Species Comparison)	$3.6x10^{-3}$	$1.2x10^{-6}$

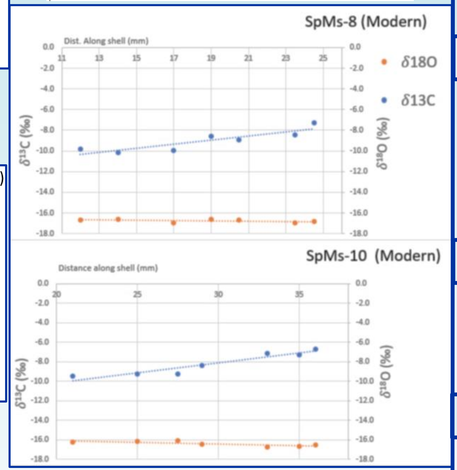

Figure 8 (Above): Isotope values across modern shells. All shells show an enrichment of $\delta^{13}C$ values over time and homogenous $\delta^{18}O$ values.

Results Cont.

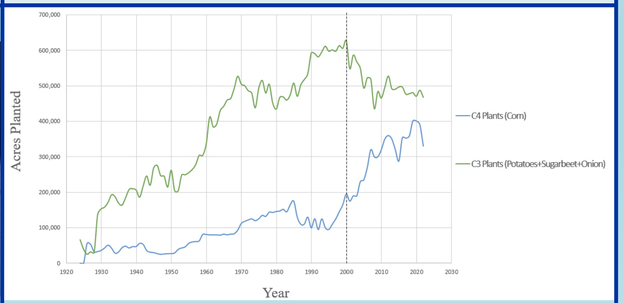

Figure 9: Acreage of C_3 (mainly potatoes, onions, and sugar beet) and C_4 plants (corn) planted in Idaho in the last century. The dashed line at 2000 CE shows a major decrease in C_3 plant production and a major increase in C_4 plant production.

Key Findings

- $\delta^{18}O$ values are homogenous across all shells, suggesting no resolvable changes to climate.
- $\delta^{13}C$ values are higher in modern shells than in ancient shells. C_4 plants have high $\delta^{13}C$ values (Farquhar et al., 1989) so they can cause such an enrichment. The massive growth in acres planted in corn, a C_4 plant, since ~2000 C.E. is a likely cause for this enrichment.
- T-tests show no significant difference in $\delta^{13}C$ and $\delta^{18}O$ between the two species of mussel in modern shells. Historic shells do show a significant difference.

Future Work

- More research into how quickly C_4 plants affect watersheds they feed into.
- Stable isotope analysis of shells dated ~5000 years old from the Holocene climatic optimum.
- Clumped isotope analysis of the samples. This is a new sampling technique that may help detect climatic changes.

Acknowledgements

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References

Epstein, S., et al. "Revised Carbonate-Water Isotopic Temperature Scale." *Geological Society of America Bulletin*, vol. 64, no. 11, 1953, p. 1315., https://doi.org/10.1130/0016-7606(1953)64[1315:rcits]2.0.co;2.

Farquhar, G D, et al. "Carbon Isotope Discrimination and Photosynthesis." *Annual Review of Plant Physiology and Plant Molecular Biology*, vol. 40, no. 1, 1989, pp. 503–537., https://doi.org/10.1146/annurev.pp.40.060189.002443.

Geist, Juergen, et al. "Stable Carbon Isotopes in Freshwater Mussel Shells: Environmental Record or Marker for Metabolic Activity?" *Geochimica Et Cosmochimica Acta*, vol. 69, no. 14, 2005, pp. 3545–3554., https://doi.org/10.1016/j.gca.2005.03.010.