You Can't Hide Your Drinking Habits: Tracking Elk with Oxygen Isotopes in Wyoming

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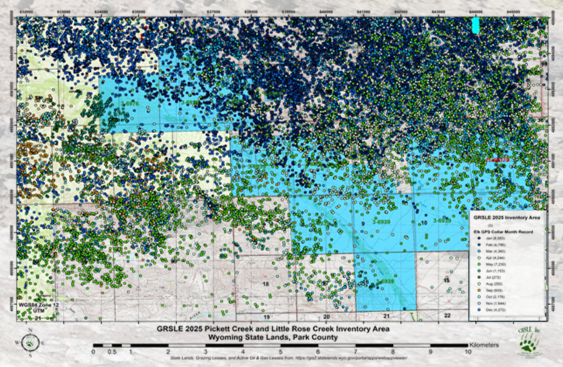
The GRSLE Project examines archaeological and ecological records in the Washakie Wilderness, with a recent focus on multi-species migration and human-animal interactions in the Greater Yellowstone Ecosystem. Stable carbon and oxygen isotope analysis of faunal tooth enamel offers a powerful tool for reconstructing seasonal mobility, dietary shifts, and climatic change. However, accurate interpretations of isotopic data depends on well-characterized, environmental reference baselines. This poster presents stage one of an isotopic survey of the Greybull River Basin, focused on modern surface waters and elk scat. Following IAEA protocols, samples were collected across diverse waterbody types (streams, wetlands, rivers, ice patches) over different seasons to evaluate spatial and temporal variability in oxygen and hydrogen isotopes. Meanwhile, elk scat representative of spring and fall 'movements' help to establish seasonal variation in carbon and nitrogen. Results will strengthen isotopic analyses of archaeological materials from the region and contribute to broader hydrological and ecological research.

INTRODUCTION

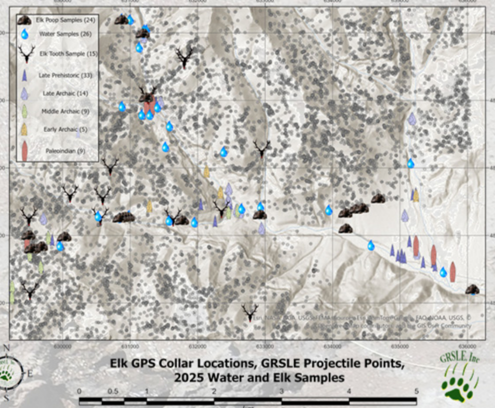
The GRSLE Project emphasizes a **transdisciplinary approach** to studying the dynamics of the Greater Yellowstone Ecosystem (GYE). Rather than focusing only on the archaeological record of human land use, GRSLE investigates how environmental, ecological, and biological processes intersect across the eastern GYE in the Shoshone National Forest. In 2024, we began developing data on the relationships between ungulate movement patterns and potential archaeological and paleontological records preserved in teeth and bones. While our long-term goal is to apply these methods to species such as bison and bighorn sheep from archaeological contexts, this initial study uses elk (*Cervus canadensis*, a well-documented species in our area) to build baseline isotopic datasets for future archaeological interpretation.



Monthly elk locations from GPS collar data.

Elk were captured between 2014 and 2017 using dart-delivered chemical immobilization and fitted with GPS collars programmed to record locations every 2–8 hours. All captures and handling were conducted under Wyoming Game and Fish Department (WGFD) Chapter 33 permits. Migration corridors were modeled using Brownian Bridge movement algorithms, incorporating location sequences from 25–50 individuals per herd. In addition to these modeled movement paths, the raw point data (shown above) are also available for analysis.

During the 2025 field season, GRSLE teams collected water samples, elk maxillary tooth rows, antlers, vegetation, and fecal material within elk winter ranges and migration corridors (map below) for oxygen isotope analysis, forming the foundation for linking modern ecological behavior with archaeological isotope records.



2025 GRSLE samples & Elk location points.

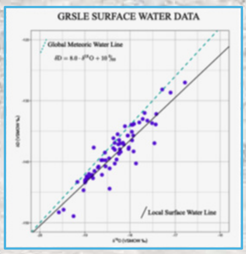
Water Sampling

The water sampling protocol followed IAEA guidelines. A Sharpie-labeled 50 mL vial was first rinsed in the surface water, then fully submerged and capped underwater. Filled vials were sealed with electrical tape and stored to prevent freezing and over-exposure to environmental variables (temperature and light). Recorded sample information included location, temperature, date, time, waterbody type, and overview photos. The 2025 program included some repeat sampling of certain water bodies over time, as well as sampling of different stream orders within the same watershed.

Thinking about integration.

Collecting Elk-Cremental Evidence

Milton and Todd collected elk and grizzly bear poo during the GRSLE field season in August 2025. Information collected for each scat includes photographs with a centimeter scale, notes on morphology—pile (summer) or pellet (winter), suspected producer (elk or bear), UTM coordinates, date and time, and a freshness rating.



LABORATORY ANALYSIS (THE ANALYTICAL POOPLINE)

Water Isotope Analysis

In total, 70 water samples were collected from 2024 to 2025. Isotopic analysis was conducted at the Environment and Natural Resources Institute Stable Isotope Lab at the University of Alaska Anchorage. Water δ^2H and δ^{18}O isotope ratios were each measured six times using a Picarro L2130-i WS-CRDS analyzer and standardized relative to the VSMOW-SLAP scale using reference standards USGS45: δ^2H = −10.30‰, δ^{18}O = −2.24‰, and USGS46: δ^2H = −235.80‰, δ^{18}O = −29.8‰).

Field sampling and lab processing.

Scat Analysis: This is How We Doo it

21 elk and 3 grizzly bear scats were collected, each weighing between 300-980 milligrams (mg). Approximately 300-500 mg of each sample was homogenized for isotopic analysis using liquid nitrogen and a metal mortar and pestle, then ~2-3mg was weighed into a tin capsule and analyzed for δ^{13}C and δ^{15}N on an EA-IRMS at the University of New Mexico Center for Stable Isotopes.

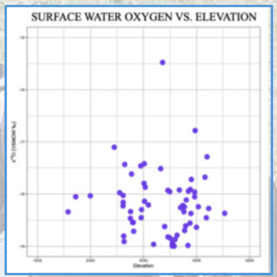
RESULTS

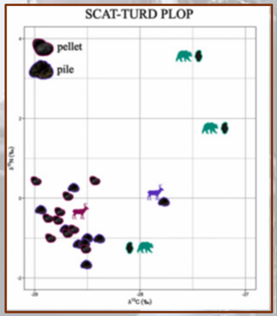
Water Isotope Results

One sample from Sag Pond produced an outlier to the dataset with a δ^{18}O value of −3.08‰. High δ^{18}O values are typical of standing water bodies due to evaporation. The mean δ^{18}O value for the remaining 69 samples, all of which represent streams, creeks, and rivers, was −18.29±0.66‰, with a range of −19.58 to −15.48‰. The mean δ^2H was −138.20±4.82‰, with a range from −148.90 to −122.64‰.

Bearly Believable Results

Previous studies have established that poos are homogenous across an event (Trentini, et al., 2025); therefore, any portion of a scat should reflect the meals that comprise it. Elk δ^{13}C values ranged from −29.0 to −27.8‰ with a mean of −27.6±0.3‰, while δ^{15}N values ranged from −2.3 to +0.4‰ with a mean of −0.7±0.7‰. Bear scat had a mean δ^{13}C value of −27.6±0.5‰ and a mean δ^{15}N value of +1.3±2.4‰.

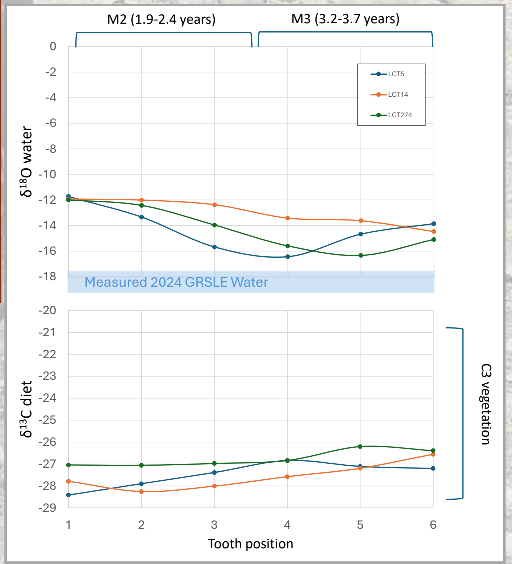




Linking Ecology and Archaeology through Isotopes

Elk Tooth Sampling and Carbonate Analysis

The upper 2nd and 3rd molars from three surface-collected elk were sequentially sampled, in the direction of growth, in three locations corresponding to early, middle, and late enamel formation. Enamel powder was treated with 2.5% NaOCl for 24 hours to remove potential organic contaminants, followed by 0.1 N acetic acid for 4 hours to remove carbonates. Samples were analyzed on a Thermo Scientific Delta V Plus mass spectrometer in continuous flow mode connected to a Gas Bench with a CombiPAL autosampler and calibrated against reference standards (NBS-18, IAEA 603). Results are reported in parts per thousand (‰).



The analytical uncertainty for δ^{13}C and δ^{18}O is ± 0.03‰ (VPDB) ± 0.09‰ (VPDB), respectively. The δ^{13}C and δ^{18}O values of elk enamel are consistent across individuals, molar, and down tooth enamel position. The mean δ^{13}C of all samples is -27.3 ± 0.6 and mean δ^{18}O is -13.8 ± 1.6.

The $\delta^{13}C_{enamel}$ values indicate a pure C3 plant diet, consistent with observations of elk ecology for the GYE region. The $\delta^{18}O_{enamel}$ values are offset from the local surface water values measured by the 2024 GRSLE team by ~1-4‰.

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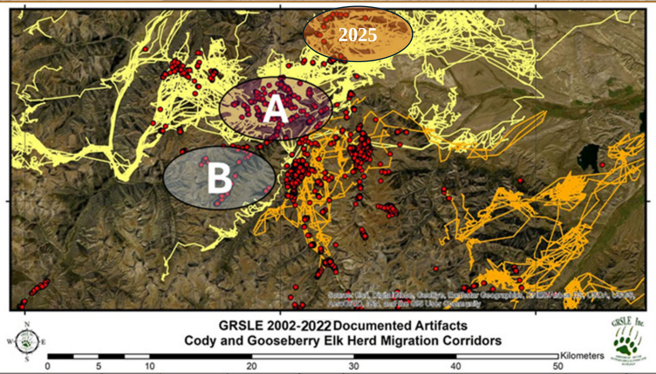
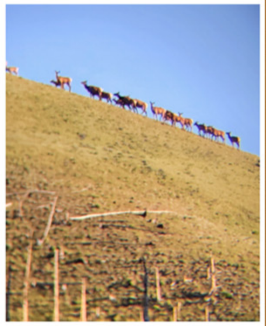
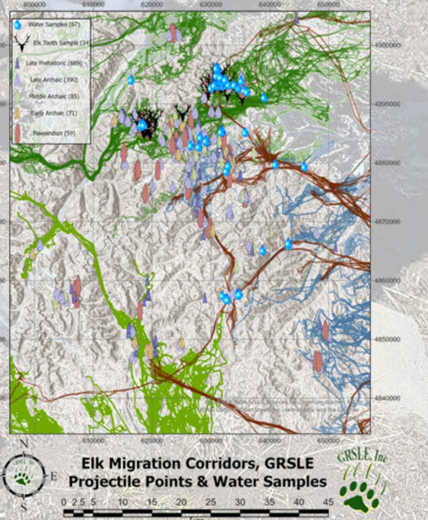


GRSLE 2002-2022 Documented Artifacts
Cody and Gooseberry Elk Herd Migration Corridors

SAMPLE AREA	INVENTORY AREA (ha)	MEAN ELEVATION (m)	ARTIFACT DENSITY (N/ha)		Locally Available Lithic Source					Non-Local Lithic Source					TOTAL
					Chalcedony (CL)	Petrified Wood (PWD)	Contact Metamorphic (SLS)	Basalt (BS)	Other Volcanic (VO)	Obsidian (OB)	Chert (CH)	Phosphoria Chert (PH)	Quartzite (QT)	Morrison Quartzite (QTM)	
A - Active Migration Corridors	567	2746	44.15	Count	8146	351	3007	370	15	1195	9593	222	1328	805	25032
				Adjusted Residual	-29.1	-16.7	11.4	1.5	1.9	8.2	15.5	5.1	4.4	13.0	
B - No Migration Corridor	238	3101	25.50	Count	3192	291	420	74	0	145	1678	15	239	15	6069
				Adjusted Residual	29.1	16.7	-11.4	-1.5	-1.9	-8.2	-15.5	-5.1	-4.4	-13.0	
TOTAL				Count	11338	642	3427	444	15	1340	11271	237	1567	820	31101





INTERPOOTATIONS

δ^{13}C and δ^{15}N values did not differ significantly between elk pellet and pile samples (mean difference = −0.13‰ and 95% Confidence Interval (CI) [−0.39, 0.14] for δ^{13}C; and 0.01‰ and 95% CI [−0.67, 0.69] for δ^{15}N). There is therefore no perceptible isotopic difference between seasonal scat from the same area, suggesting that any measured δ^{13}C or δ^{15}N change in incremental elk tissues (hair, teeth, or antlers) would be more likely attributable to migration than seasonal baseline change. The range of δ^{15}N variation for the bear scat is intriguing, and may be due to inter-individual differences, dietary changes, or even taphonomy (Trentini, et al., 2025).

While our interpretations of the water isotope data remain preliminary, we suggest that this dataset does not show major patterning across elevation, over seasons, or within the catchment. While values are within the range of δ^{18}O values published for the state, they are on the lower end of this range (www.waterisotopes.org). Again, this likely suggests any major shifts in elk tissues reflect large-scale migration to different watersheds.

References

Trentini, I.P., Magioli, M., Grotta-Neto, F., Peres, P.H.d.F., Ferraz, K.M.P.M.B., Moreira, M.Z., Oliveira, M.L.d., Duarte, J.M.B., 2025. Confounding factors in the isotopic analysis of herbivore fecal samples, *Eur J Wildlife Res* 71.

Poster Copy

We are working to investigate relationships between ungulate migration corridors and regional archaeology.