

Exploring Landscapes Dynamics: Integrating Multi-dimensional Regional Datasets from the Greater Yellowstone Ecosystem

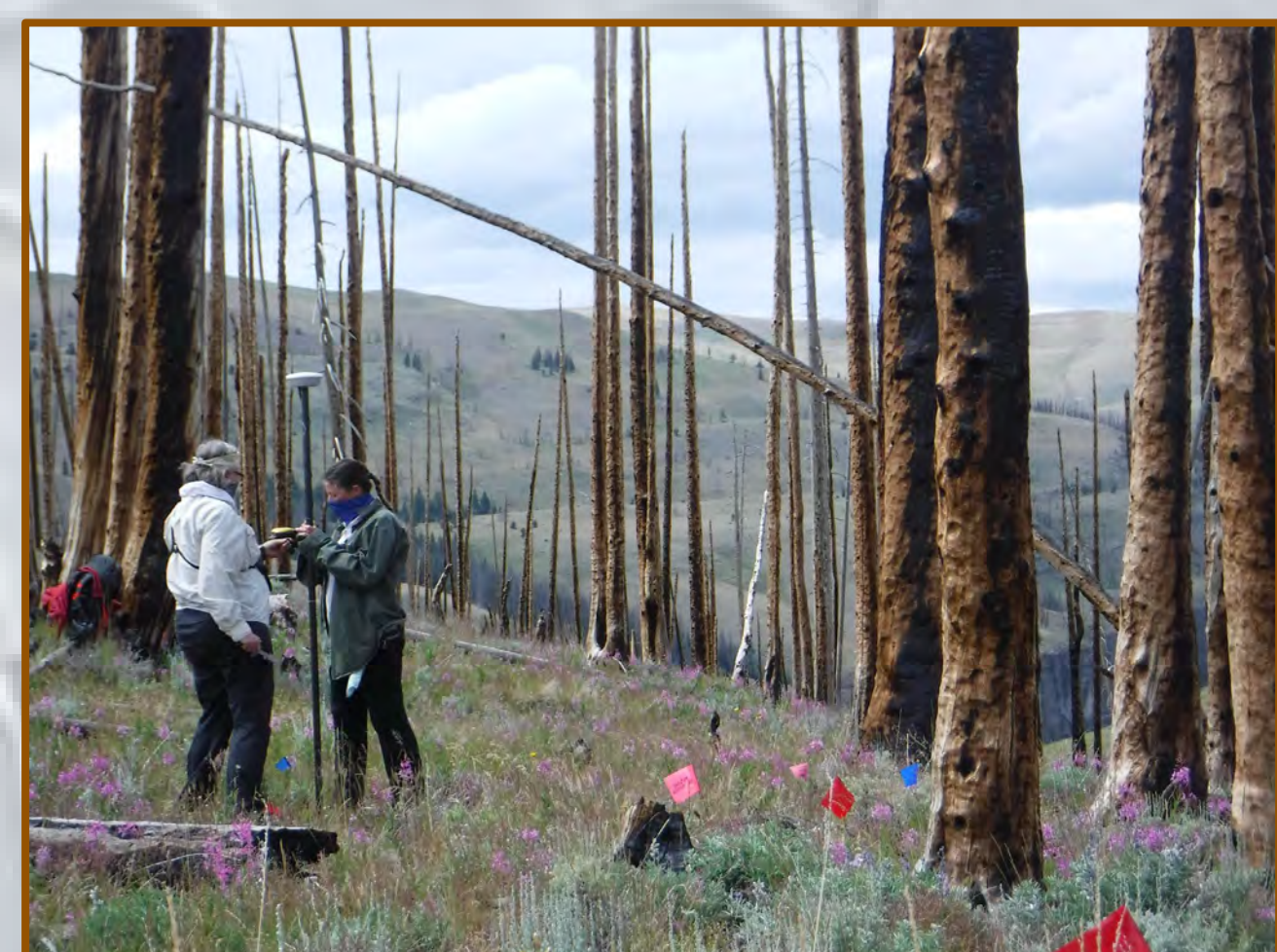
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RESEARCH FRAMEWORK

The study of contemporary systems can provide insights into past human-environment dynamics. We ask:
Q: How do human and other animal systems converge in the Greater Yellowstone Ecosystem?
Q: How do water isotopologues, elk migration corridors, and raw material usage vary over space and time?
Q: How do elk tooth carbonates relate to documented landscape systems?

FIELD DATA COLLECTION

Since 2022 the GRSLE project has conducted artifact-based archaeological field work in the Greater Yellowstone Ecosystem (GYE). Currently, the cumulative artifact locational and descriptive database contains over a quarter million records of stone tools and debitage. A total of 12,118 pieces of obsidian have been recorded in the project area; 1,458 have been geochemically sourced using edXRF and more are under study using pXRF. Based on diagnostic projectile point raw material data, obsidian use in the GRSLE project area increased through time, with 74.4% of the 254 obsidian points being Late Prehistoric. This suggests that obsidian use may have more temporal overlap with recent, documented landscape properties such as migration corridors and water chemistry.



Elk (*Cervus canadensis*) were captured during 2014–2017 via dart-delivered chemical immobilization and fitted with GPS collars programmed to record a location every 2–8 hours. Capture and handling were conducted in compliance with WGF Chapter 33 permits. Migration corridors were developed from Brownian bridge movement models using collar location sequences for 25–50 individuals in each herd. The GRSLE field teams collected elk maxillary tooth rows and antlers within the migration corridors for isotopic analysis.



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. During the preliminary sampling season, locations targeted rivers within the 2024 GRSLE field area. One sampling location, WY-CC-01, was sampled four times over three weeks to test temporal variability.



ABSTRACT

Incorporating interpretations about the dynamics of past movements into the static archaeological record presents significant challenges. Opportunities to explore the connections between movement, landscape, and the physical evidence of changing locations are rare. Since 2002, the GRSLE project has focused on high elevations (generally above 2500 m) in the Greater Yellowstone Ecosystem, documenting regional-scale surface archaeology and seeking to better understand the movement and use of these mountainous areas by past human populations. Concurrently, a large-scale regional dataset on ungulate migration patterns has been assembled. To build a more comprehensive understanding of regional, multi-species movement patterns, we are investigating the relationships between archaeological surface distributions, contemporary ungulate migration corridors, biogeochemical signatures of regional faunal remains, and water isotope geochemistry. Initial results from this transdisciplinary research provide a robust foundation for both enhancing our understanding of past human-environment interactions and modeling future trends.

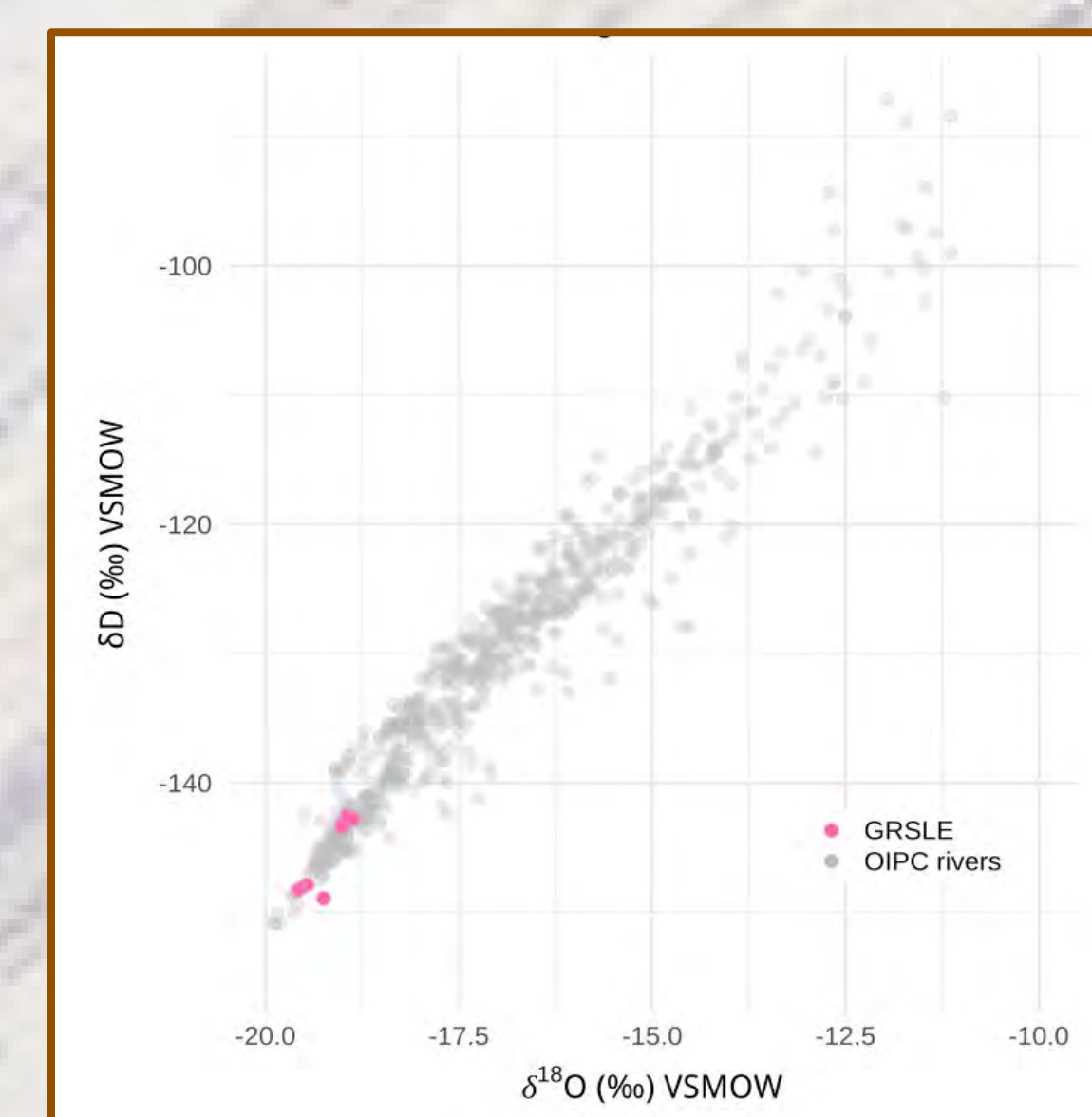
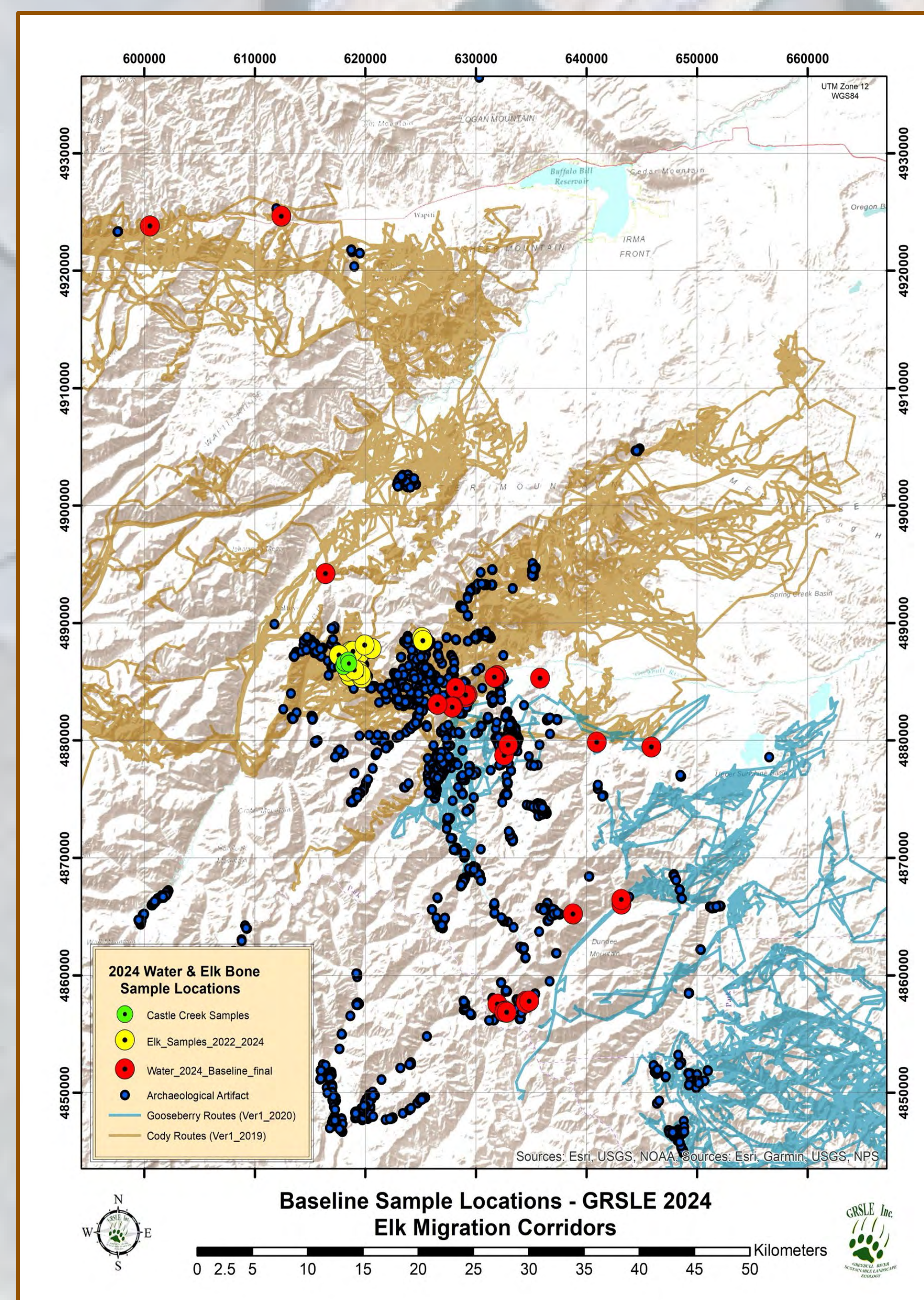
LABORATORY ANALYSIS AND RESULTS

Water Isotope Analysis

Isotopic analysis was conducted at the Environment and Natural Resources Institute Stable Isotope Lab at the University of Alaska Anchorage. Water δ^2H and $\delta^{18}O$ 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: $\delta^2H = -10.30\text{‰}$, $\delta^{18}O = -2.24\text{‰}$, and USGS46: $\delta^2H = -235.80\text{‰}$, $\delta^{18}O = -29.8\text{‰}$.

The mean $\delta^{18}O$ value was $-19.11 \pm 0.26\text{‰}$, with a range from -18.82‰ to -19.58‰ ; mean δ^2H was $-144.72 \pm 2.58\text{‰}$, with a range of -142.56‰ to -148.90‰ . Sample precision for $\delta^{18}O$ was 0.07‰ and 0.34‰ for δ^2H . For the samples collected over three weeks at location 1, the mean $\delta^{18}O$ value was $-18.97 \pm 0.03\text{‰}$, and the mean δ^2H was $-142.85 \pm 0.29\text{‰}$. The standard deviation for both the $\delta^{18}O$ and δ^2H measurements was less than machine precision, suggesting no significant variation occurred over this period. For all samples, despite the variation in sampling locations, any observed variation would be imperceptible at the level of mammalian consumption.

The 2024 GRSLE surface water data are consistent with the lowest values previously measured in Wyoming basins, based on published values from waterisotopes.org. The range of variation captured across large sections of the elk migration corridor suggests the $\delta^{18}O_{\text{enamel}}$ values from regional elk may provide a reliable marker of movement. However, other variables, such as seasonal change, merit further testing, as the magnitude of seasonal variation could overprint a 'migration signal'.

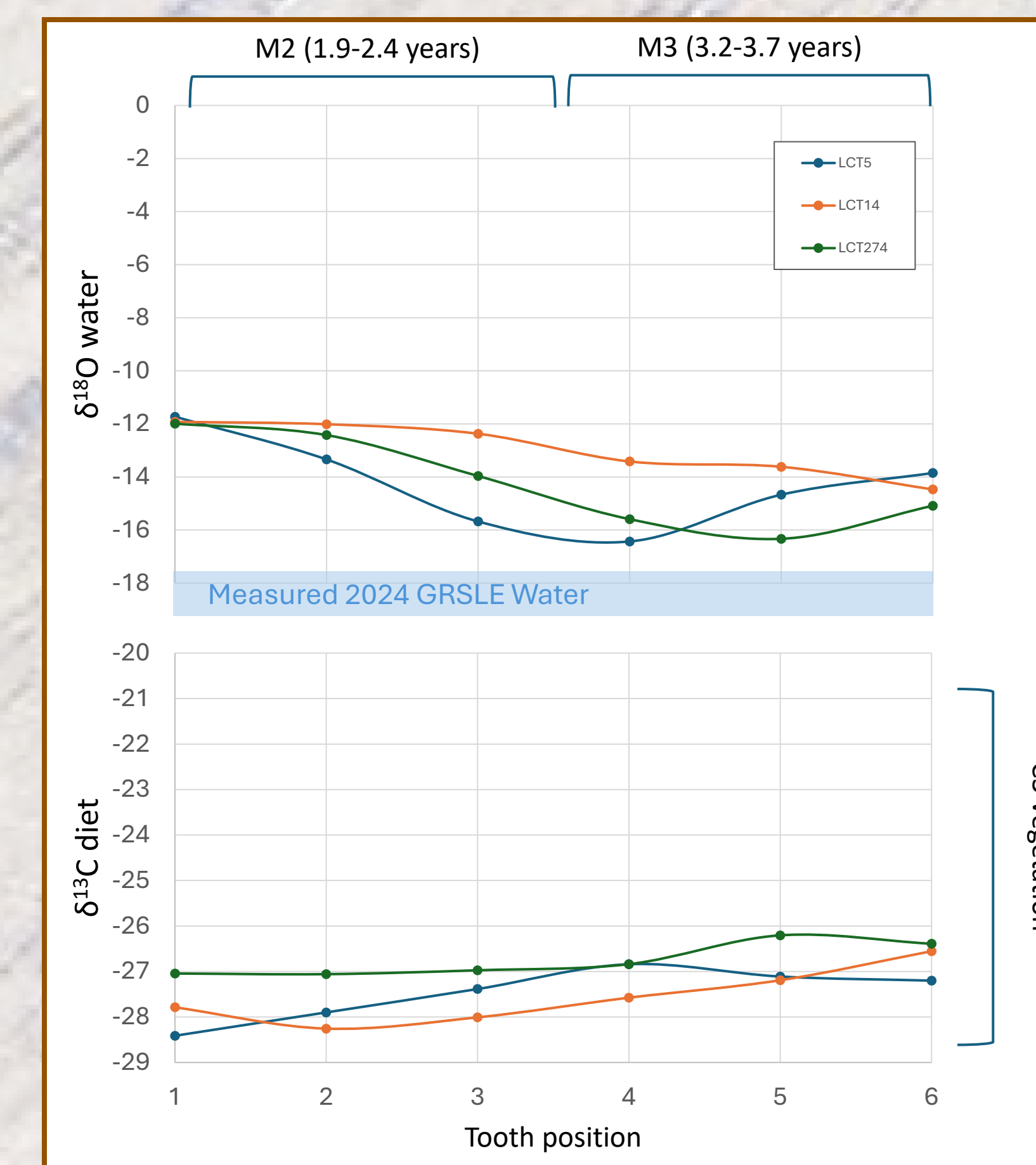


SYNTHESIS AND FUTURE WORK

We collected data from archaeological raw materials, elk migration routes, scavenged animal carcasses, and surface waters to understand long-term human-ecosystem dynamics in the GYE. Data suggest a significant overlap between past human activity areas and contemporary elk ranges. Future work will focus on increased spatiotemporal water and vegetation sampling to document baseline processes; increased tooth collection and isotopic analyses to understand behavioral variation captured in past and known animals; continued monitoring of wild elk populations; and expanded pXRF analysis of surface-collected archaeological obsidian.

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 (‰).



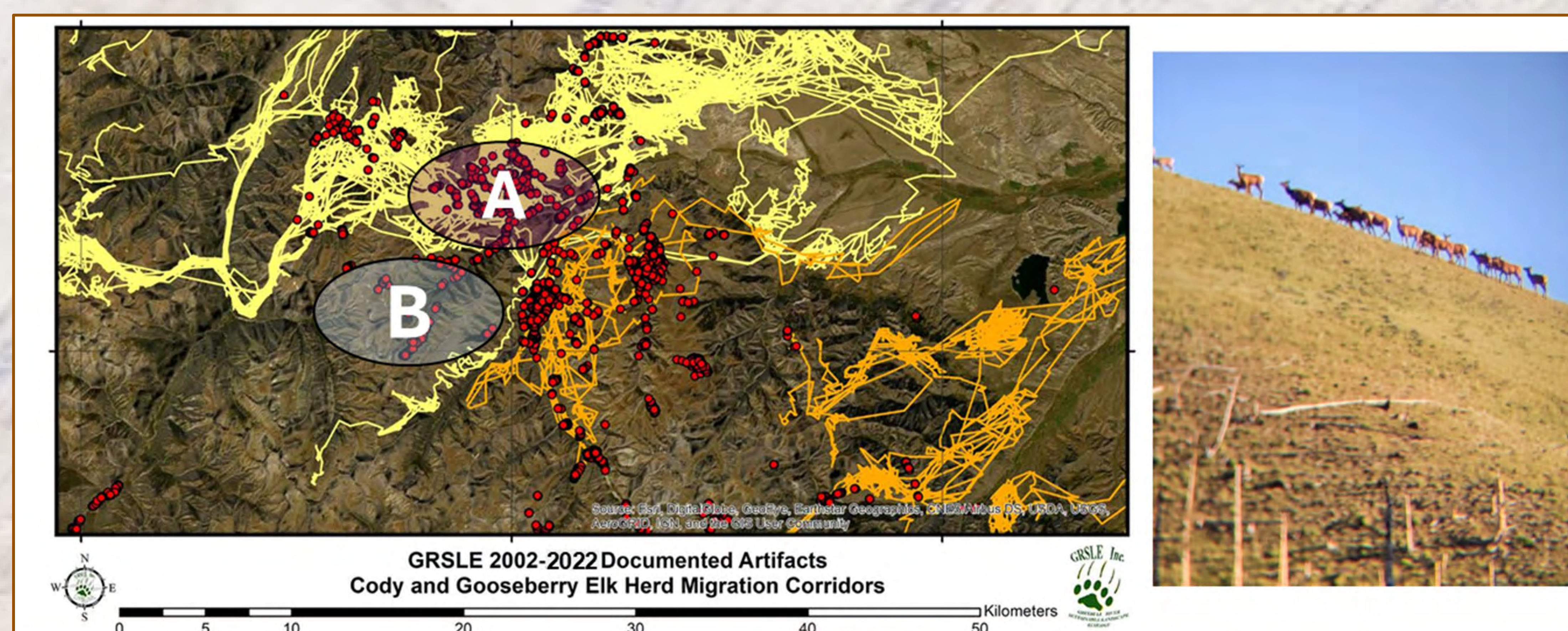
The analytical uncertainty for $\delta^{13}C$ and $\delta^{18}O$ is $\pm 0.03\text{‰}$ (VPDB) $\pm 0.09\text{‰}$ (VPDB), respectively. The $\delta^{13}C$ and $\delta^{18}O$ values of elk enamel are consistent across individuals, molar, and downturn enamel position. The mean $\delta^{13}C$ of all samples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

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

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Obsidian Source Locations and Elk Migration Trails

Tracing artifacts to raw material sources can provide insight into possible relationships between elk migration corridors and past human landscape use. Transport of obsidian suggests that human connections to the west are greater along migration corridors than in other areas of the Absarokas.



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

