Stacks

Supplemental Information: Seasonal diets, trace minerals, heavy metals, and body condition: nutritional characteristics of barren ground caribou in Southwest Alaska

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Conflicts of Interest
The authors declare no conflicts of interest.

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Supplemental Material

This supplement provides additional data and analytical details referenced in the main manuscript, including detailed forage isotope values (Table S1), statistical outputs from redundancy analyses (Tables S2–S3), and supporting figures illustrating an overall conceptual model (Figure S1), diet source polygons (Figure S2), isotope variation by lactation status and year (Figure S3), and isotopic niche breadth (Figure S4). These materials are intended to enhance transparency and support interpretation of the study's findings.

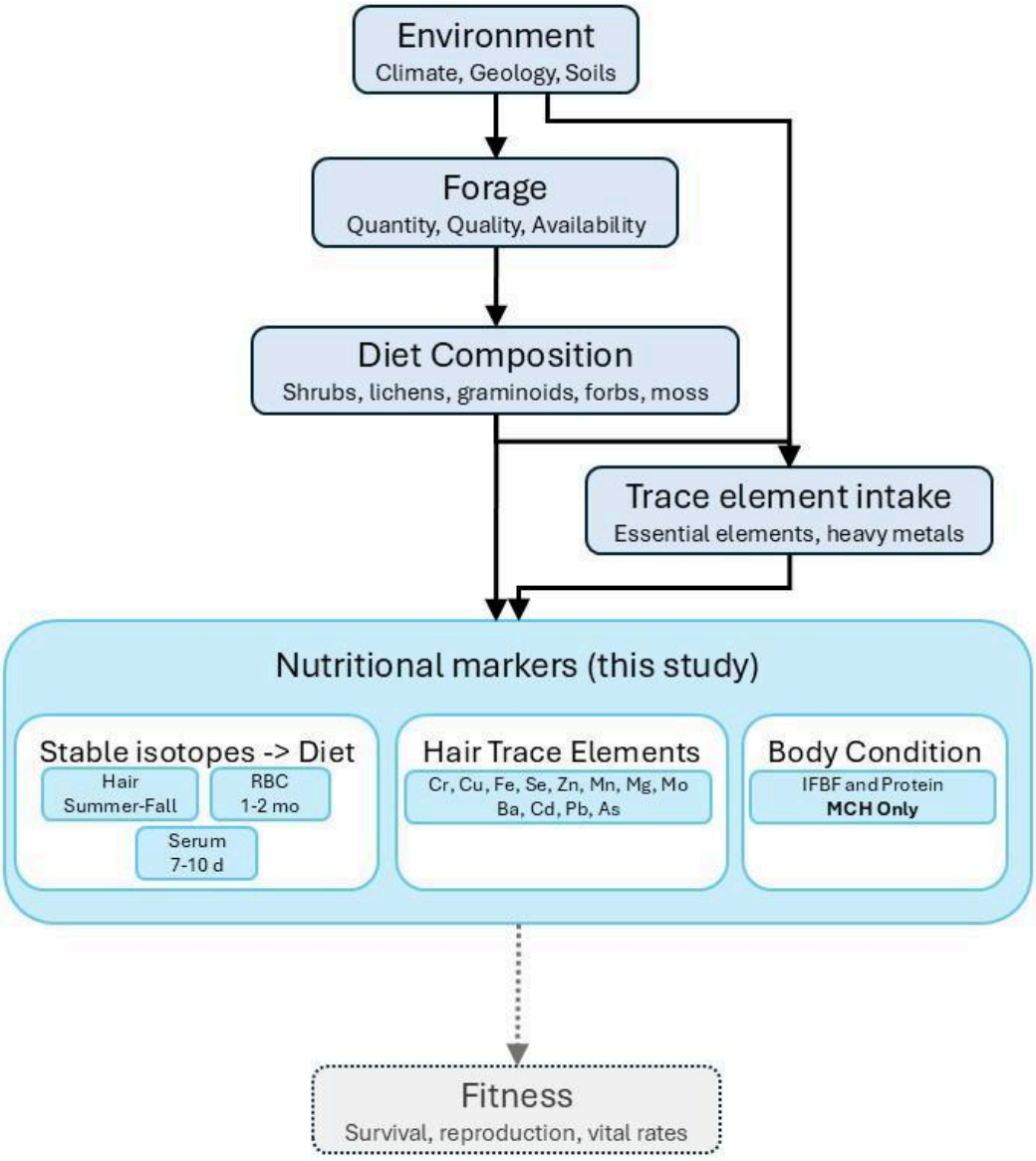

Figure S1. Conceptual model illustrating the analytical approach to nutrition taken in this study. Environment shapes forage characteristics including nutritional quality and trace element content. Forage characteristics determine diet composition and trace element intake. Diet composition and trace element intake drive stable isotope variation in tissues, trace elements in hair, and body condition (assessed in the MCH only), the metrics we measured. Fitness outcomes were not directly measured.

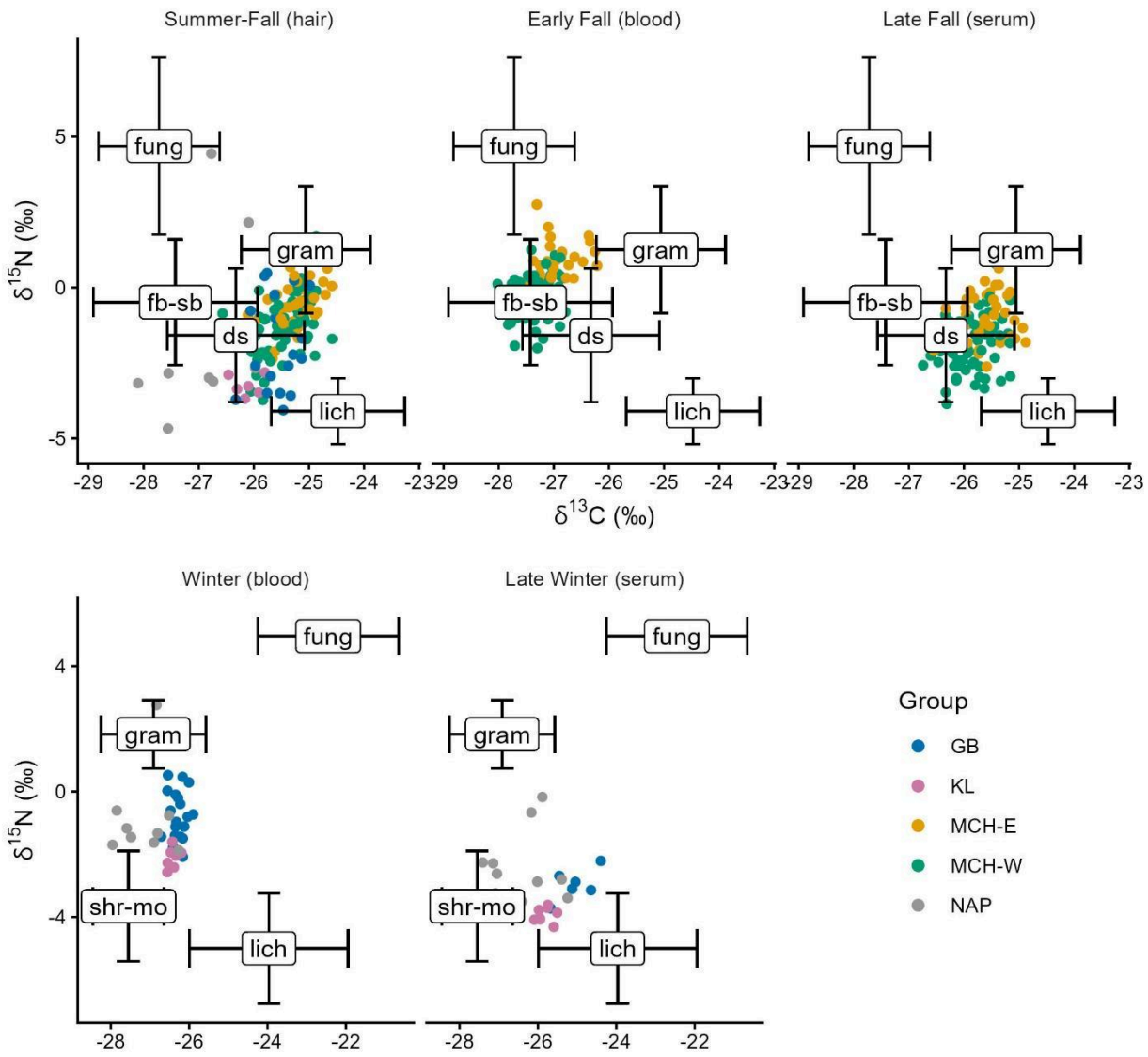

Figure S2. Diet sources and tissues of all animals in dual isotope space (i.e. "source polygons"), 2020- 2022. Top row: summer through fall diet items from the more intensive summer vegetation sampling plotted with isotope values from the second 2 cm of hair growth in 2022, and fall sampled red blood cells and serum.Bottom row: Winter through spring diet items from the first vegetation sampling plotted with isotope values from the late winter sampled serum and red blood cells, and the first 2 cm of hair growth in 2022. Tissue specific discrimination factors (TDFs) are subtracted from displayed caribou tissue values. Diet sources are displayed as mean ± SD. Note: SD whiskers in the bottom row are obscured by the PFT label for fungi, but they are ± 0.41 ‰.

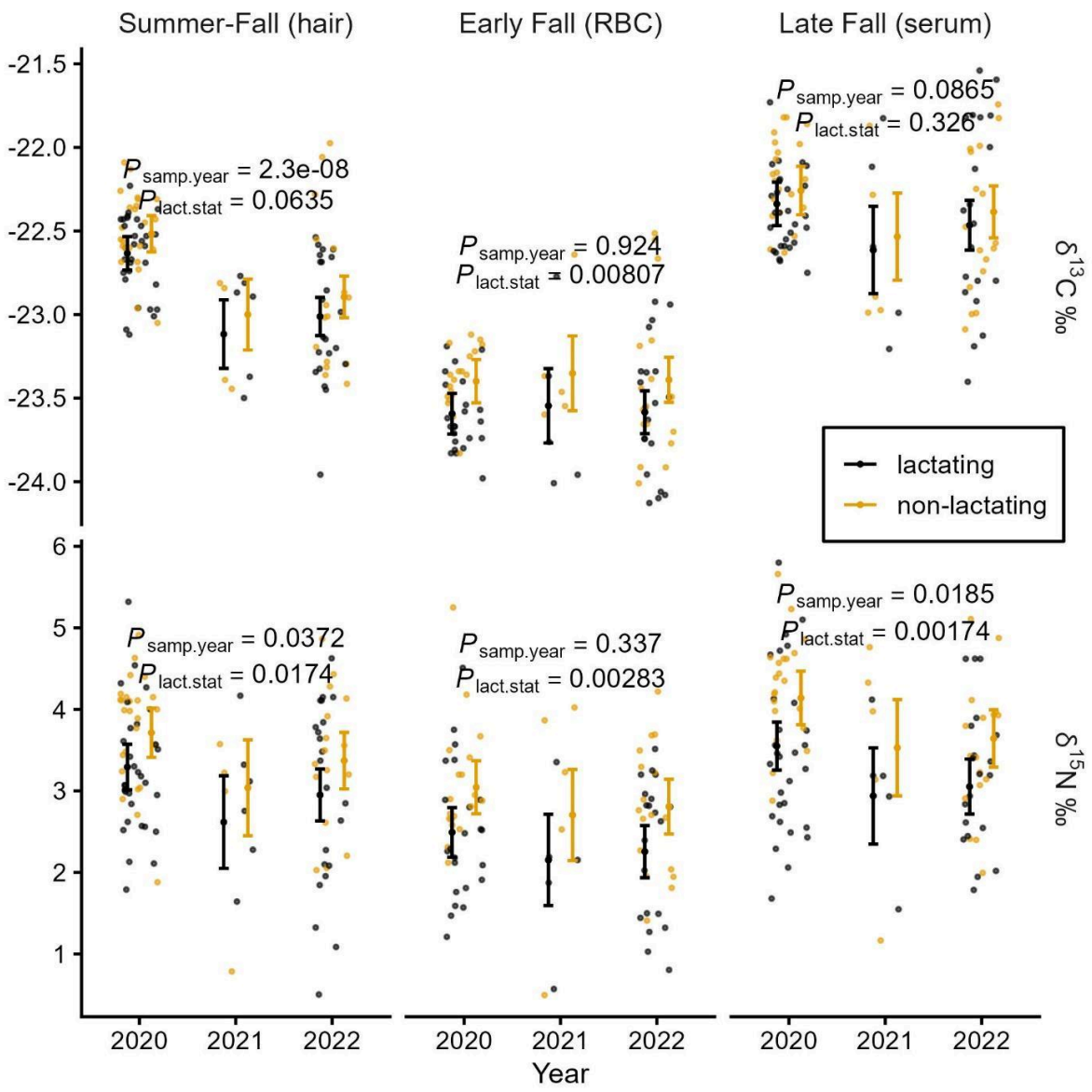

Figure S3. Stable isotope values ($\delta^{13}C$ and $\delta^{15}N$) of female caribou from the Mulchatna herd, Southwest Alaska, 2020–2022, shown by lactation status and sample year across three tissue types (hair, RBC, and serum). Additive linear models were fit separately for each tissue × isotope combination, with lactation status and sample year included as fixed effects. Type II ANOVA P-values for each predictor are displayed within panels, and model-estimated marginal means (± 95% CI) are plotted alongside individual observations. Effects of lactation status were generally small relative to among-individual variation, and although some year effects were detected, only one year of source isotope data was

available; therefore, isotope data were pooled across lactation groups and years for diet modeling.

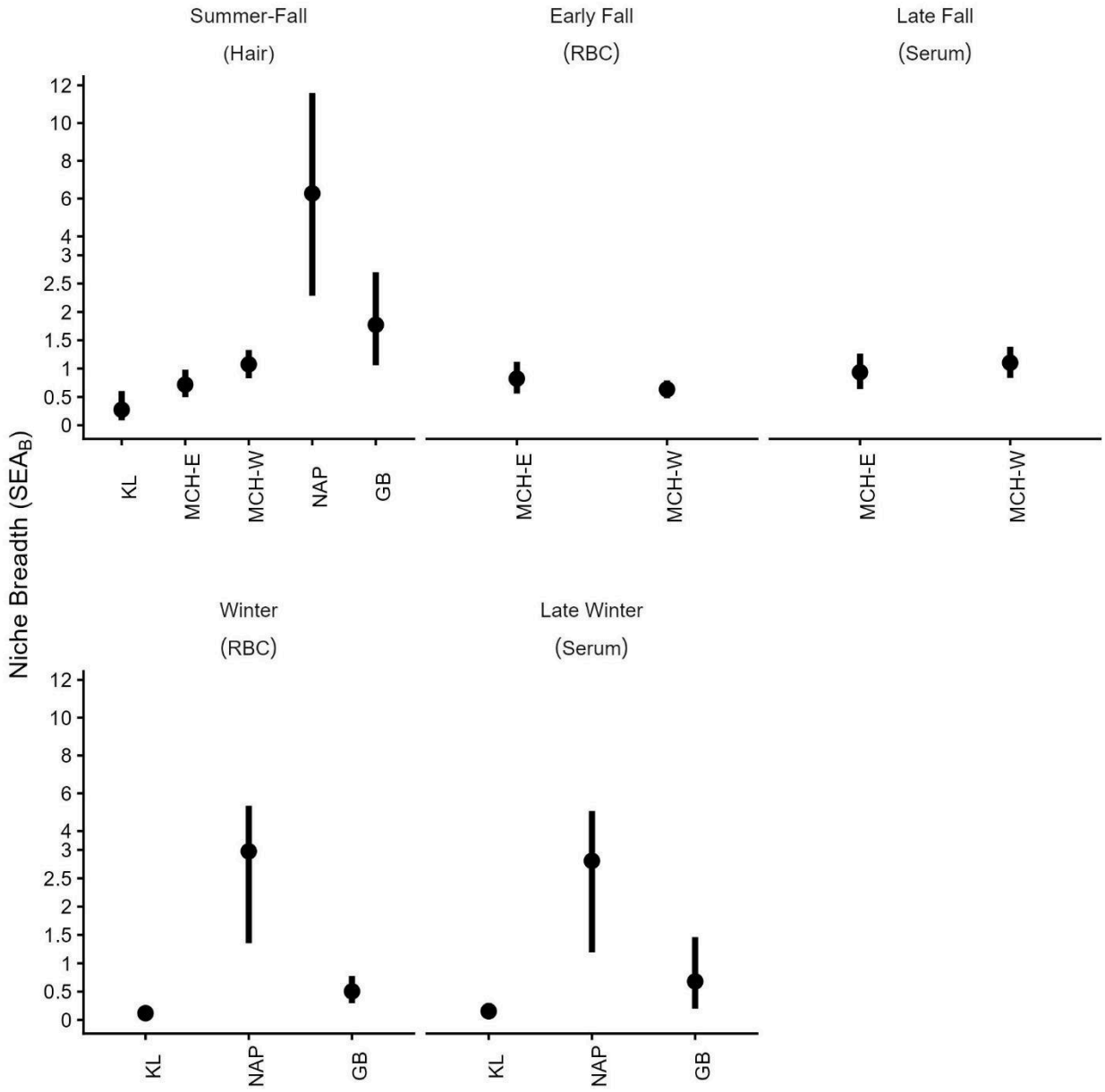

Figure S4. Isotopic niche breadth (unitless, 95% credible intervals) for Southwest Alaska caribou groups, 2020-2023. Note: y-axis is compressed above 4 to make it easier to see smaller values.

Table S1. Carbon (%), Nitrogen (%), $\delta^{13}C$ (‰), and $\delta^{15}N$ (‰) content, and sample month and year of forage species in Southwest Alaska, 2021-2022.

Genus		Species	C (%)	N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Date Collected
Deciduous Shrubs	*Betula*	*nana*	50.7	2.1	-26.64	-4.36	6/2022
	Betula	*nana*	51	1.5	-27.37	-1.11	6/2022
	Betula	*nana*	49.9	1.4	-26.21	-2.49	6/2022
	Betula	*nana*	49.7	2.1	-26.99	-3.54	6/2022
	Betula	*nana*	48.2	2.3	-28.72	0.19	6/2022
	Betula	*nana*	49.8	1.7	-27.23	-5.03	6/2022
	Betula	*nana*	50.7	1.7	-25.34	-6.31	6/2022
	Betula	*nana*	48.8	3.4	-28.27	-2.35	6/2022
	Betula	*nana*	49.7	2.2	-27.3	-5.61	6/2022
	Betula	*nana*	49.9	1.7	-26.44	-0.53	6/2022
	Betula	*nana*	51.2	1.8	-27.14	-1.64	6/2022
	Betula	*glandulosa*	51.2	2.3	-26.4	2.44	6/2022
	Betula		53.3	2.6	-28.19	-4.8	5/2021
	Betula		53.3	2.6	-28.19	-4.8	5/2021
	Rubus	*arcticus*	45.6	3	-28.18	-1.06	6/2022
	Salix	*fuscescens*	49.6	2.1	-26.61	0.91	6/2022
	Salix	*fuscescens*	49.7	2.5	-25.68	0	6/2022
	Salix	*barclayi*	50.5	3	-25.79	-3.94	6/2022
	Salix	*barclayi*	49.2	1.8	-28.66	-1.95	6/2022
	Salix	*barclayi*	51	3.1	-28.36	1.02	6/2022
	Salix	*barclayi*	51.4	2.7	-26.71	-0.12	6/2022
	Salix	*phlebophylla*	49.1	1.6	-26.11	-0.8	6/2022
	Salix	*phlebophylla*	50.8	1.9	-25.65	0.66	6/2022
	Salix	*phlebophylla*	49.7	1.6	-26.14	-1.4	6/2022
	Salix	*phlebophylla*	49.5	1.7	-27.12	-3.19	6/2022
	Salix		48.8	4.2	-26.62	-1.68	5/2021
	Salix		48.8	4.2	-26.62	-1.68	5/2021
	Salix	*arctica*	46.8	1.5	-26.17	1.32	6/2022
	Salix	*arctica*	49	2	-27.2	-1.22	6/2022
	Salix	*pulchra*	50.7	2.8	-24.43	-1.93	6/2022
	Salix	*pulchra*	50.1	1.6	-26.7	-1.51	6/2022
	Salix	*pulchra*	50.3	2.8	-24.01	-4.85	6/2022
	Salix	*pulchra*	49.6	1.9	-25.06	-2.54	6/2022
	Salix	*pulchra*	51.1	2.5	-25.7	-0.9	6/2022
	Spirea	*stevenii*	48.4	2.6	-24.34	1.84	6/2022
	Spirea	*stevenii*	49.9	2.2	-25.21	-1.63	6/2022
	Spirea	*stevenii*	49.2	2.1	-24.07	-0.32	6/2022
	Spirea	*stevenii*	48.6	2.6	-25.6	-4.58	6/2022
	Spirea	*stevenii*	50.1	1.8	-25.48	2.34	6/2022
	Spirea	*stevenii*	48.5	2.5	-24.69	-2.96	6/2022
	Spirea	*stevenii*	48.3	2.7	-26.42	-1.28	6/2022
Evergreen Shrubs	*Andromeda*	*polifolia*	50.5	1.2	-26.89	-7.33	6/2022
	Andromeda		53.4	1.5	-26.34	-2.64	5/2021
	Andromeda		53.4	1.5	-26.34	-2.64	5/2021
	Arctous	*alpina*	49.7	1.6	-27.11	1.37	6/2022
	Arctous	*alpina*	49.9	1.7	-27.87	-0.25	6/2022
	Arctous	*alpina*	49.3	2	-27.48	-1.77	6/2022
	Arctous	*alpina*	49.1	2.2	-28.49	-8.31	6/2022
	Arctous	*alpina*	49.9	1.5	-26.88	-1.81	6/2022
	Diapensia	*obovata*	48.2	1	-27	-3.45	6/2022
	Empetrum	*nigrum*	52.7	1.5	-25.26	-6.73	6/2022

	Genus	Species	C (%)	N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Date Collected
	Empetrum	*nigrum*	52.2	1	-26.31	-5.68	6/2022
	Empetrum	*nigrum*	53.7	1.1	-24.07	-6.42	6/2022
	Empetrum	*nigrum*	52.2	1.5	-25.62	-5.55	6/2022
	Empetrum	*nigrum*	54.3	1.9	-25.27	-5.48	6/2022
	Empetrum	*nigrum*	53.2	1.6	-25.85	-0.24	6/2022
	Empetrum	*nigrum*	53.5	1.3	-25.32	-5.79	6/2022
	Empetrum	*nigrum*	53.7	0.9	-25.83	-4.2	6/2022
	Empetrum	*nigrum*	53.8	1	-26.17	-2.31	6/2022
	Kalmia	*procumbens*	55	0.9	-28.51	-8.44	6/2022
	Kalmia	*procumbens*	55.9	0.6	-28.88	-5.1	6/2022
	Kalmia	*procumbens*	54.3	0.8	-26.65	-6.18	6/2022
	Kalmia	*procumbens*	55.8	0.7	-27.63	-5.41	6/2022
	Kalmia	*procumbens*	55.4	0.8	-28.97	-4.81	6/2022
	Ledum		51.6	0.5	-27.33	-4.53	5/2021
	Ledum		51.6	0.5	-27.33	-4.53	5/2021
	Rhododendron	*tomentosum*	52.9	1.3	-26.68	-3.41	6/2022
	Rhododendron	*tomentosum*	54	1.3	-27.83	-4.73	6/2022
	Rhododendron	*tomentosum*	53	1.7	-26.44	-4.36	6/2022
	Rhododendron	*tomentosum*	52.9	1.6	-26.34	-6.78	6/2022
	Rhododendron	*tomentosum*	54	1	-27.25	-8.55	6/2022
	Rhododendron	*tomentosum*	54.2	1.3	-25.99	-6.56	6/2022
	Rhododendron	*tomentosum*	52.7	1.8	-27.5	-1.04	6/2022
	Rhododendron	*tomentosum*	52.5	1.4	-26.19	-4.36	6/2022
	Rhododendron	*tomentosum*	52.6	1.4	-26.44	-5.47	6/2022
	Rhododendron	*tomentosum*	52	1.7	-27.13	-4.6	6/2022
	Vaccinium	*vitis-idaea*	51.5	1.4	-27.57	-6.95	6/2022
	Vaccinium	*vitis-idaea*	49.5	1	-27.63	-7.2	6/2022
	Vaccinium	*vitis-idaea*	51.6	1.2	-27.55	-9.98	6/2022
	Vaccinium	*vitis-idaea*	50.8	1.1	-28.05	-6.61	6/2022
	Vaccinium	*vitis-idaea*	51.6	0.8	-29.07	-4.59	6/2022
	Vaccinium	*vitis-idaea*	51.6	0.8	-29.07	-4.59	6/2022
	Vaccinium	*vitis-idaea*	49.6	1.3	-26.98	-6.8	5/2021
	Vaccinium	*vitis-idaea*	51.3	0.7	-28.1	-5.18	5/2021
	Vaccinium	*vitis-idaea*	51.1	0.9	-27.8	-5.39	6/2022
Forbs	*Achillea*	*millefolium*	43.9	4.4	-29.46	-0.63	6/2022
	Anemonastrum	*richardsonii*	45.3	3	-27.93	-2.47	6/2022
	Anemone	*parviflora*	46.7	2.5	-25.47	-0.29	6/2022
	Angelica	*lucida*	45.7	4.4	-25.94	-0.92	6/2022
	Antennaria	*friesiana*	44.1	1.6	-27.43	1.35	6/2022
	Arnica	*frigida*	43.2	1.9	-28.67	-0.99	6/2022
	Arnica	*frigida*	44.1	1.8	-26.28	0.67	6/2022
	Arnica	*frigida*	46.6	1.9	-26.63	-2.3	6/2022
	Bistorta	*plumosa*	48.4	3.2	-26.07	0.71	6/2022
	Chamaenerion	*angustifolium*	47.2	3.5	-25.78	0.87	6/2022
	Chamaenerion	*angustifolium*	46.9	2.5	-26.33	-4.12	6/2022
	Chamaenerion	*angustifolium*	44.5	4	-27.9	-1.98	6/2022
	Chamaenerion	*angustifolium*	45.9	3.9	-28.86	-1.95	6/2022
	Chamaenerion	*angustifolium*	46.3	3.3	-25.63	2.84	6/2022
	Cherleria	*arctica*	45.6	1.4	-27.5	2.45	6/2022
	Cherleria	*arctica*	46.3	2.3	-25.07	3.61	6/2022
	Gerianium	*erianthum*	46.7	3.4	-28.18	-2.06	6/2022
	Gerianium	*erianthum*	45.6	2.9	-27.5	-4.19	6/2022
	Oxytropis	*bryophila*	46.8	2.2	-27.13	-1.93	6/2022
	Pedicularis	*labrodorica*	46.1	2.4	-28.86	-4.76	6/2022
	Pedicularis	*labrodorica*	45.3	2.5	-29.58	-2.14	6/2022
	Pedicularis	*capitata*	46.1	1.9	-27.06	-1.48	6/2022

Genus		Species	C (%)	N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Date Collected
	Pyrola	*asarifolia*	47.9	1.7	-28.44	-1.48	6/2022
	Rhodiola	*integrifolia*	45.9	3.8	-28.17	-1.37	6/2022
	Rubus	*chaemaemorus*	46.2	2.9	-26.61	1.31	6/2022
	Rubus	*chaemaemorus*	47.8	2.6	-25.33	0.68	6/2022
	Rubus	*chaemaemorus*	47.8	2.8	-24.91	2.83	6/2022
	Sanguisorba	*canadensis*	45.7	3.7	-25.77	-1.81	6/2022
	Sanguisorba	*canadensis*	44.8	3	-27.77	-0.58	6/2022
	Streptopus	*amplexifolius*	48.4	4.5	-29.28	-0.15	6/2022
	Trientalis	*europaea*	46	3.4	-29.06	-1.93	6/2022
	Trientalis	*europaea*	48	2	-27.68	-1.66	6/2022
	unknown		46.8	3.2	-27.33	6.76	5/2021
	unknown		46.8	3.2	-27.33	6.76	5/2021
	Valeriana	*sitchensis*	48.4	3.2	-28.37	-0.08	6/2022
	Viola	*langsdorfii*	46.6	5	-29.61	-0.96	6/2022
Fungi	unknown		44.9	2	-20.9	4.61	5/2021
	unknown		44.9	2	-20.9	4.61	5/2021
	unknown		47.4	4.1	-24.01	5.31	5/2021
	unknown		47.4	4.1	-24.01	5.31	5/2021
Graminoids	*Calamogrostis*	*canadensis*	44.9	2.4	-23.97	0.41	6/2022
	Calomagrostis	*canadensis*	47.5	3.3	-24.6	5.17	6/2022
	Calomagrostis	*inexpansa*	46.4	2.8	-25.23	2.93	6/2022
	Calomagrostis	*inexpansa*	45.3	1.5	-27.06	-0.98	6/2022
	Calomagrostis	*canadensis*	45.7	4	-26.33	0.38	6/2022
	Carex	*microchaeta*	44.7	2.1	-26.2	2.27	6/2022
	Carex	*microchaeta*	44.3	2.3	-25.53	0.13	6/2022
	Carex	*aquatilis*	46.3	2	-25.29	0.43	6/2022
	Carex	*bigelowii*	46	2.9	-23.99	1.11	6/2022
	Carex	*bigelowii*	46	1.5	-23.55	0.15	6/2022
	Carex	*bigelowii*	45.8	1.6	-24.76	-0.74	6/2022
	Carex	*bigelowii*	45.7	2.2	-22.82	4.03	6/2022
	Carex	*aquatilis*	46.3	2.8	-24.32	3.53	6/2022
	Carex	*microchaeta*	45.2	1.2	-27.22	-0.55	6/2022
	Carex	*microchaeta*	44.8	1.6	-25.1	2.35	6/2022
	Eriophorum	*vaginatum*	47.6	1.7	-25.43	1.93	6/2022
	Eriophorum	*angustifolium*	46.2	2.3	-24.5	5.02	6/2022
	HierochlÃ¶e	*alpina*	44.1	1.3	-23.89	-1.75	6/2022
	HierochlÃ¶e	*alpina*	44.6	1.6	-24.28	-2.49	6/2022
	Luzula	*multiflora*	46	1.9	-26.59	1.54	6/2022
	Trisetum	*spicatum*	45.7	1.3	-25.52	1.42	6/2022
	unknown		45.7	2.1	-28.09	2.05	5/2021
	unknown		45.7	2.1	-28.09	2.05	5/2021
	unknown		46.6	1	-27.49	0.85	5/2021
	unknown		46.6	1	-27.49	0.85	5/2021
	unknown		45.1	3.7	-25.95	3.28	5/2021
	unknown		45.1	3.7	-25.95	3.28	5/2021
	unknown		44.6	0.5	-24.64	2.34	5/2021
	unknown		44.6	0.5	-24.64	2.34	5/2021
	unknown		46.1	2.6	-28.35	2.33	5/2021
	unknown		46.1	2.6	-28.35	2.33	5/2021
	unknown		41.4	0.5	-26.96	0.12	5/2021
	unknown		41.4	0.5	-26.96	0.12	5/2021
Lichens	*Cetrari*		44.5	0.2	-20.43	-6.43	5/2021
	Cetraria		44.5	0.2	-20.43	-6.43	5/2021
	Cetraria		41.5	0.3	-22.4	-7.25	5/2021
	Cetraria		41.5	0.3	-22.4	-7.25	5/2021
	Cetraria		45	0.2	-22.93	-6.61	5/2021

Genus		Species	C (%)	N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Date Collected
	Cetraria		45	0.2	-22.93	-6.61	5/2021
	Cetraria						5/2021
	Cetraria						5/2021
	Cladina		42.1	0.3	-22.7	-6.17	5/2021
	Cladina		42.1	0.3	-22.7	-6.17	5/2021
	Cladina		43	0.3	-24.43	-6.12	5/2021
	Cladina		43	0.3	-24.43	-6.12	5/2021
	Cladina		44.3	0.3	-22.92	-4.68	5/2021
	Cladina		44.3	0.3	-22.92	-4.68	5/2021
	Cladina		44.7	0.3	-24.75	-5.01	5/2021
	Cladina		44.7	0.3	-24.75	-5.01	5/2021
	Cladina		44.9	0.4	-25.23	-4.97	5/2021
	Cladina		44.9	0.4	-25.23	-4.97	5/2021
	unknown		41.4	0.4	-25.94	-3.11	6/2022
	unknown		44.1	0.3	-25.44	-3.37	6/2022
	unknown		42.4	0.3	-23.13	-3.98	6/2022
	unknown		43.5	0.4	-23.1	-3.47	6/2022
	unknown		41.6	0.3	-24.3	-4.41	6/2022
	unknown		43	0.3	-24.51	-6.12	6/2022
	unknown		43.3	0.3	-25.98	-3.09	6/2022
	unknown		41.8	0.4	-23.38	-5.2	6/2022
	unknown		43.8	0.3	-24.5	-5.35	6/2022
	unknown		43.8	0.3	-24.5	-5.35	6/2022
	unknown		44	0.3	-24.81	-5.11	6/2022
	unknown		44	0.3	-24.81	-5.11	6/2022
	unknown		48.6	1.6	-29.33	-0.38	6/2022
	unknown		48.6	1.6	-29.33	-0.38	6/2022
	unknown		46.5	0.6	-23.65	-3.35	6/2022
	unknown		46.5	0.6	-23.65	-3.35	6/2022
Moss	unknown		45.6	0.5	-27.12	-4.33	5/2021
	unknown		45.6	0.5	-27.12	-4.33	5/2021
	unknown		45.7	0.6	-27.16	-3.57	5/2021
	unknown		45.7	0.6	-27.16	-3.57	5/2021
	unknown		37.5	0.8	-27.36	0	5/2021
	unknown		37.5	0.8	-27.36	0	5/2021
	unknown		45.1	0.5	-29.05	-4.02	5/2021
	unknown		45.1	0.5	-29.05	-4.02	5/2021
	unknown		47.7	0.5	-27.27	-6.4	5/2021
	unknown		47.7	0.5	-27.27	-6.4	5/2021
Spore-Bearers	*Diphasiastrum*	*complanatum*	45.2	1.1	-29.05	-1.67	6/2022
	Diphasiastrum	*alpinum*	44.7	1.4	-29.85	-1.13	6/2022
	Dryopteris	*expansa*	46.4	2.6	-24.24	4.74	6/2022
	Dryopteris	*expansa*	44.8	2.3	-26.78	-0.17	6/2022
	Equisetum	*arvense*	42.6	3.4	-26.04	1.31	6/2022
	Gymnocarpium	*dryopteris*	48.2	3.7	-28.09	-1.78	6/2022
	Spinulum	*annotinum*	48.7	1.2	-28.61	0.68	6/2022
	Spinulum	*annotinum*	48.2	1.1	-28.93	2.5	6/2022

Table S2. Summary of redundancy analysis ordination evaluating the relationship between group, lactation status, trace minerals, heavy metals, and $\delta^{15}N$ and $\delta^{13}C$ in hair from Southwest Alaska female caribou. *P* values in **bold** indicate a significant effect of the term on $\delta^{15}N$ and $\delta^{13}C$ at the $P \leq 0.05$ level.

Term	**df**	**Variance**	***F***	***P***
Group	4	0.746	14.665	**0.001**
Barium	1	0.019	1.464	0.188
Chromium	1	0.042	3.275	0.051
Copper	1	0.027	2.091	0.113
Lead	1	0.005	0.432	0.582
Selenium	1	0.029	2.253	0.099
Zinc	1	0	0.029	0.96
Iron	1	0.002	0.128	0.844
Magnesium	1	0.013	1.01	0.338
Residual	88	1.119		

Table S3. Summary of redundancy analysis ordination evaluating the relationship between subgroup (East or West), lactation status, trace minerals, heavy metals, and $\delta^{15}N$ and $\delta^{13}C$ (left) or ingesta-free body fat (IFBF) and total body protein (TBP) in hair from Mulchatna herd (MCH) female caribou in Southwest Alaska. *P* values in **bold** indicate a significant effect of the term on $\delta^{15}N$ and $\delta^{13}C$ in MCH female caribou at the $P \leq 0.05$ level. Iron was excluded from the body condition RDA analysis due to its high variance inflation factor.

	Response vars: $\delta^{15}N$ and $\delta^{13}C$				Response vars: IFBF and TBP			
Term	**df**	**Variance**	***F***	***P***	**df**	**Variance**	***F***	***P***
Subgroup	1	0.222	11.76	**0.001**	1	0.001	0.045	0.955
Lactation Status	1	0.08	4.224	**0.026**	1	0.393	16.987	**0.001**
Barium	1	0.097	5.118	**0.015**	1	0.009	0.385	0.657
Chromium	1	0.097	5.142	**0.014**	1	0.024	1.033	0.349
Copper	1	0.04	2.098	0.138	1	0.002	0.07	0.93
Lead	1	0.069	3.664	0.051	1	0.013	0.575	0.569
Manganese	1	0.008	0.446	0.62	1	0.064	2.768	0.071
Selenium	1	0.016	0.87	0.368	1	0.047	2.014	0.126
Zinc	1	0.035	1.853	0.167	1	0.049	2.109	0.135
Iron	1	0.027	1.447	0.248	–	–	–	–
Magnesium	1	0.08	4.212	**0.032**	1	0.032	1.391	0.249
Residual	65	1.228	–	–	59	1.366	–	–