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Article abstract

The stable isotope analysis of preserved proteinaceous tissues, such as bone collagen and hair keratin, offers a powerful means of examining individual dietary practices in archaeology and, through this, inferring the subsistence behaviours, socio-cultural practices, and food preferences of past populations. Previous isotope research at the precontact Yup'ik village site of Nunalleq, Alaska, has provided evidence of a mixed diet of marine and terrestrial foods (but likely dominated by salmonids), but also highlighted some dietary variability amongst the inhabitants of the site. However, materials from the older rescue excavations were insufficient to infer whether this variability was interpersonal and/or diachronic in nature. Here, new stable carbon and nitrogen isotope data from human hair are presented. These were obtained during the research excavations at Nunalleq from temporally constrained, well-stratified contexts. The new data reveal dietary change through time at the site, highlighting changes in resource use and subsistence practices during the Little Ice Age. During the middle phase of occupation at the site (Phase III; cal AD 1620–1650), diet is more varied, most likely relating to the differing relative contribution of salmon versus higher trophic level marine mammal protein to the diet of some individuals at the site. Analysis reveals these differences to be site-spatial, possibly indicating differences with the use of space at the site, and/or hinting at possible social differentiation in diet during Phase III. In the final occupation phase (Phase II; cal AD 1640–1660), diet is more homogeneous and demonstrates an increased exploitation of higher-trophic level marine foods.

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ABSTRACT

The stable isotope analysis of preserved proteinaceous tissues, such as bone collagen and hair keratin, offers a powerful means of examining individual dietary practices in archaeology and, through this, inferring the subsistence behaviours, socio-cultural practices, and food preferences of past populations. Previous isotope research at the precontact Yup'ik village site of Nunalleq, Alaska, has provided evidence of a mixed diet of marine and terrestrial foods (but likely dominated by salmonids), but also highlighted some dietary variability amongst the inhabitants of the site. However, materials from the older rescue excavations were insufficient to infer whether this variability was interpersonal and/or diachronic in nature. Here, new stable carbon and nitrogen isotope data from human hair are presented. These were obtained during the research excavations at Nunalleq from temporally constrained, well-stratified contexts. The new data reveal dietary change through time at the site, highlighting changes in resource use and subsistence practices during the Little Ice Age. During the middle phase of occupation at the site (Phase III; cal AD 1620–1650), diet is more varied, most likely relating to the differing relative contribution of salmon versus higher trophic level marine mammal protein to the diet of some individuals at the site. Analysis reveals these differences to be site-spatial, possibly indicating differences with the use of space at the site, and/or hinting at possible social differentiation in diet during Phase III. In the final occupation phase (Phase II; cal AD 1640–1660), diet is more homogeneous and demonstrates an increased exploitation of higher-trophic level marine foods.

KEYWORDS

Palaeodiet, keratin, Alaska, precontact, hunter-gatherer-fisher, marine foragers, Yup'ik

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RÉSUMÉ

Nouvelles données isotopiques mettant en évidence l'organisation spatiale et les variations temporelles dans l'alimentation précontact durant le Petit Âge glaciaire à Nunalleq (sud-ouest de l'Alaska)

L'analyse des isotopes stables de tissus préservés riches en protéines, comme le collagène osseux et la kératine capillaire, est une approche puissante d'examiner les pratiques alimentaires individuelles en archéologie et, par conséquent, d'inférer les comportements de subsistance, les pratiques socio-culturelles et les préférences alimentaires des populations passées. Une étude précédente sur les isotopes menée sur le site précontact du village Yup'ik de Nunalleq (Alaska), a mis en évidence un régime alimentaire mixte composé de ressources marines et terrestres (vraisemblablement dominé par les salmonidés), mais également une certaine variabilité alimentaire entre les habitants du site. Toutefois, le matériel provenant des fouilles de sauvetage plus anciennes n'était pas suffisant pour déterminer si cette variabilité était diachronique ou due à des différences inter-individuelles. Nous présentons ici de nouvelles données sur les isotopes stables du carbone et de l'azote provenant de cheveux humains. Celles-ci ont été obtenues à Nunalleq lors de fouilles effectuées en contexte bien stratifié et chronologiquement bien défini. Les nouvelles données révèlent un changement de régime alimentaire au court du temps, mettant en évidence des changements dans les modes de subsistance et l'utilisation des ressources pendant le Petit Âge Glaciaire. Pendant la phase intermédiaire d'occupation du site (phase III ; 1620-50 après J.C. cal), le régime alimentaire est plus varié, très probablement en raison de la variation dans la contribution relative du saumon et des protéines de mammifères marins de niveau trophique supérieur dans l'alimentation de certains individus sur le site. L'analyse révèle que ces différences sont d'ordre spatial, ce qui pourrait indiquer des différences quant à l'utilisation de l'espace sur le site et/ou suggérer une éventuelle différenciation sociale dans l'alimentation pendant la phase III. Lors de la phase finale d'occupation (phase II ; 1640-60 après J.C. cal), le régime alimentaire est plus homogène, révélant une exploitation accrue de ressources d'origine marine de niveau trophique supérieur.

MOTS-CLÉS

Palaeodiète, keratin, Alaska, précontact, chasseur-cueilleur-pêcheur, cueilleur marin, Yup'ik

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The reconstruction of subsistence strategies is integral to our understanding of hunter-gatherer societies in the past and can illuminate past human–environmental interactions and adaptations, particularly in high-latitude environments. The study of dietary practices can also reveal key aspects about past sociocultural practices, individual and group preferences, and identities (Gumerman 1997; Hastorf 2016; Mintz and Du Bois 2002; Samuel 1996; Smith 2006). Subsistence practices and diet in the Yukon–Kuskowim (Y–K) Delta are ethnographically well documented, and targeted a wide variety of faunal species, including seals, salmon, caribou, birds, and marine fish (Barker and Barker 1993; Fitzhugh and Kaplan 1982; Spray Starks 2001; Spray Starks 2007). However, even early ethnographic accounts of subsistence are inappropriate analogues for precontact practices in the region, not least in light of the pronounced climate changes experienced in Alaska over the past millennia (Hu et al. 2001; Mann 2007), or the profound and dramatic impact of Euro-American contact on life in the Y–K Delta (Fienup-Riordan and Rearden 2012, 17)

In Alaskan archaeology, the reconstruction of past diets and subsistence strategies has relied primarily upon analysis of faunal assemblages; lithic, antler, bone, and wooden artefact, as well as on ethnography and oral histories. While these proxies provide a good picture of general subsistence activities, the stable isotope analysis of human tissues is a useful additional tool in archaeology as it can provide an estimate of foods consumed, offering an opportunity to reconstruct the diets of ancient humans directly from their physical remains. Stable isotope data can therefore provide unique dietary perspectives on the scale of individual lives, but also enable intra- and cross-site comparison, illuminating past dietary variability on multiple levels (Britton 2017).

The carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values of bodily proteins such as keratin and bone collagen reflect the $\delta^{13}C$ and $\delta^{15}N$ values of ingested dietary protein (DeNiro and Epstein 1978, 1981; Schoeninger and DeNiro 1984), with only minor contributions from other dietary macronutrients (Froehle, Kellner, and Schoeninger 2010; Warinner and Tuross 2009). Carbon isotope ratios ($\delta^{13}C$) are used to discriminate between marine and terrestrial dietary protein sources, and nitrogen isotope ratios ($\delta^{15}N$) can be used to determine the trophic level of the protein consumed. In general, $\delta^{15}N$ values increase by 3 to 5 ‰ with each step up the food chain, whereas $\delta^{13}C$ values are enriched by ~1 ‰. $\delta^{15}N$ values can also be used to indicate freshwater or marine dietary inputs, as aquatic ecosystems tend to have longer food chains (Richards et al. 2001). In these ways, the measurement of $\delta^{13}C$ and $\delta^{15}N$ values of humans and different animal species can allow the reconstruction of trophic relationships within archaeological ecosystems, and allow the identification of likely sources of human dietary protein. Different bodily tissues offer different temporal resolution: bone collagen can indicate long-term (~10 years or more) dietary isotopic averages (Ambrose and Norr 1993; Hedges et al. 2007), whereas human hair, for example, grows at a rate of ~1 cm per month in humans, and thus provides a short-term record of diet (Lamb 2016).

Previous isotopic research at Nunalleq has focused on the human hair found commonly at the site, as well as zooarchaeological remains, examining dietary practices of the past inhabitants of the site (human and canine), and even the migratory ecology of key prey species, such as caribou (Britton et al. 2013; Britton et al. 2018; Gigleux et al. 2019; McManus-Fry et al. 2018). The isotope analysis of large quantities of human hair from non-mortuary contexts on preserved house floors has provided an overview of precontact subsistence at the site, indicating a mixed diet, incorporating marine and terrestrial resources, but especially rich in salmonids (Britton et al. 2013; Britton et al. 2018). To date, however, these analyses have been constrained to the materials unearthed during the initial rescue excavations of the site, which included field seasons in 2009 and 2010. These excavations focused on Area C only (see Figure 1) and mean that initial isotope studies included material from a mix of archaeological levels dated from throughout the period of site occupation (late fourteenth/fifteenth until seventeenth century AD). In light of this, it was unknown if variability within the dataset from the site was related to interpersonal dietary differences, or was instead a function of more general differences in time related to changes in resource availability, acquisition, or use. More recent field seasons (2013–2015) focused on Area A and a midden (Area B), and employed single context recording. This approach has allowed a site matrix to be produced (see Branch et al. 2005, 34), which has in turn enabled an advanced programme of radiocarbon dating that includes Bayesian modelling (Ledger et al. 2018), identifying and dating successive phases of construction, occupation, and remodelling events at the site. Zooarchaeological analysis of material from the more recent research excavations have revealed possible diachronic trends in resource procurement and use across these different occupation events, particularly regarding the proportion of fish and marine mammals (see Figure 1; adapted from Masson-MacLean et al. 2019, Figure 4).

In this study, in order to explore possible diachronic change in diet at Nunalleq and/or spatial variability in contemporary contexts across the site, further analyses on human hair found on preserved house floors during the research excavations were conducted.

Materials and Methods

Materials

Non-mortuary human hairs were selected from the site of Nunalleq (GDN-248), close to the village of Quinhagak, Alaska. Nunalleq was a densely occupied village site of semi-subterranean sod houses. Permafrost and waterlogged soils led to the preservation of tens of thousands of in situ artefacts on house floors, and an extensive assemblage of organic ecofactual and bioarchaeological remains, including cut strands of human hair. The material utilised in this study originates from the 2013, 2014, and 2015 field seasons, which are stratigraphically well sequenced and dated. Material originates from the

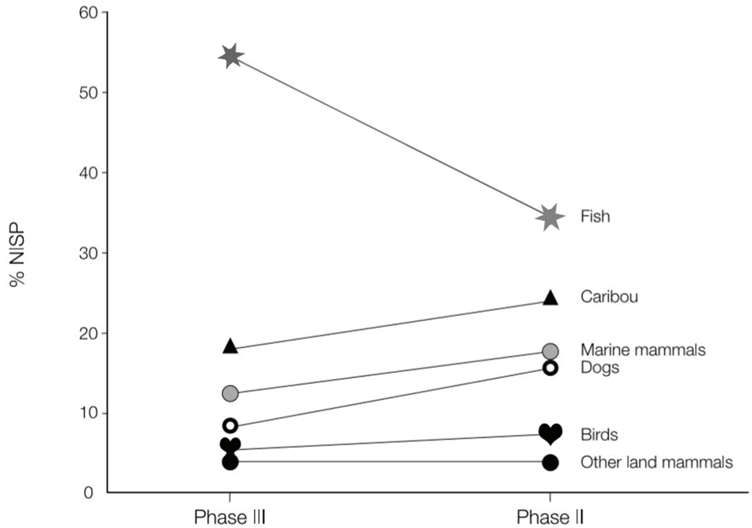

Figure 1. Taxonomic spectrum (Number of Identified Specimens, or %NISP) from Nunalleq Phases III (cal AD 1620–1650), and II (cal AD 1640 and 1660), adapted from Masson-MacLean et al. (2019, Figure 4). Dates from Ledger et al. (2018).

middle and latest phases of occupation at the site, Phase III and II, respectively. While being stratigraphically discernible, date estimates for the beginning of Phase III and II and the final destruction of the site present a large degree of temporal overlap, implying that the events likely occurred over a very short period indeed (Ledger et al. 2018, 519). Both phases began with episodes of architectural remodelling. Calibrated radiocarbon dates from the site indicate that occupation during Phase III likely began between cal AD 1620–50, lasting for a period of thirty to thirty-five years. Phase II followed another phase of remodelling (occurring between cal AD 1640–1660), and is estimated to have been shorter, at a maximum of twenty-five years. Samples utilized here originate from house floors related to the occupation events associated with Phase III and Phase II, known as Event H (Phase III) and Event F (Phase II) (Ledger et al. 2018).

Hair samples selected for this study (n=47) consisted of short discrete locks of cut human hair (~2–6 cm in length), excavated in situ from preserved house floors. Their origin is non-mortuary and the hair most likely represents domestic debris accidentally or intentionally discarded following haircuts. Sub-samples of groups of hairs (20–30 hairs) from the same lock were selected and prepared for analysis. Samples were judged to be from different individuals on the basis of their different cut lengths, texture, colour, and strand thickness. However, without genetic screening, it was not possible to avoid duplication in sampling entirely; that is, it is possible that some hair samples may originate from the same individuals, cut at the same time, or even in a different season or year. As the length of the cut strands varied, and human hair grows at a rate of approximately 1 cm per month (Valkovic 1977), the hair samples included in this studied represent a dietary history of between approximately two to six months.

Methods

Human hair samples were prepared for isotope analysis at the Department of Archaeology, University of Aberdeen (Aberdeen, UK) and measured at the Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany). Samples were prepared using standard protocols to degrease and clean samples (see Britton et al. 2018, after O'Connell and Hedges 1999; O'Connell et al. 2001; Hedges, Thompson, and Hull 2005), before being weighed into tin capsules for carbon and nitrogen isotope analysis. Carbon and nitrogen content, and carbon and nitrogen isotope ratios ($\delta^{13}C$, $\delta^{15}N$) were determined using EA/CF-IRMS (ThermoFinnigan Flash EA 22112 coupled to a Delta Plus XP isotope ratio mass spectrometer). $\delta^{13}C$ values are reported relative to the Vienna Pee Dee Belemnite (V-PDB) standard, and $\delta^{15}N$ values were measured relative to the ambient inhalable reservoir (AIR) standard. Analytical precision on the $\delta^{13}C$ and $\delta^{15}N$ values was calculated from the repeat measurements of internal and international standards and was ±0.2 ‰ (1σ) or better.

Results and Discussion

The bulk stable isotope data (along with the %C, %N, and C:N ratio) of all samples are shown in Table 1. C:N ratio can provide a general indication of sample quality (O'Connell and Hedges 1999) and is commonly employed in archaeological studies to assess preservation (e.g., Britton et al. 2018; Knüsel et al. 2010). In our study, the C:N ratios of all samples comply with the range of values in modern human hair (~3.0–3.8; O'Connell and Hedges 1999; O'Connell et al. 2001). While it should be noted that bulk fibre C:N ratio is not as sensitive an indicator of degradation as, for example, amino acid composition (see Von Holstein et al. 2016), the range of values exhibited in the Nunalleq samples, coupled with the permafrost conditions at the site and the preservation of diagnostic microscopic structures within individual hairs of both humans and animals at the site (Masson-MacLean, McManus-Fry, and Britton 2020; Skillin 2016), suggests keratinous fibres at Nunalleq are physically and isotopically well preserved.

Table 1. Human hair stable carbon and nitrogen isotope data from the research excavations at Nunalleq (n=47). Analytical precision was ±0.2 ‰ (1σ) or better.

Sample (S-#)	Context ID	Square	Structure	Phase	Event	δ^{13}C (‰)	δ^{15}N (‰)	%C	%N	C:N
14214	14069	67	Str1	II	F	-15.7	16.6	45.3	15.7	3.4
14160	14065	44	Str1	II	F	-16.3	16.7	46.8	16.2	3.4
14148	14065	66	Str1	II	F	-15.7	16.6	45.6	15.8	3.4
1204	13014	34	Str2	II	F	-15.4	17.4	43.3	14.2	3.6
1228	13014	23	Str2	II	F	-15.7	16.9	42.6	13.4	3.7
1215	13014	23	Str2	II	F	-16.4	16.4	44.1	14.0	3.7
1227	13014	23	Str2	II	F	-15.6	16.9	44.2	14.2	3.6
1282	13014	23	Str2	II	F	-15.9	17.0	43.0	13.6	3.7
1207	13014	23	Str2	II	F	-16.9	16.4	43.4	13.6	3.7
1382	13125	24	Str2	II	F	-16.0	15.9	44.5	14.0	3.7
1053	13014	22	Str2	II	F	-15.3	17.5	48.5	16.8	3.4
1295	13014	24	Str2	II	F	-15.4	18.0	47.7	16.7	3.3
1350	13014	24	Str2	II	F	-16.5	16.3	49.9	17.2	3.4
14337	14098	53	Str5	II	F	-15.1	17.2	48.2	16.9	3.3
15184	15067	120	Str6	II	F	-16.3	16.5	49.0	17.1	3.3
1070	13019	91	Str11	II	F	-15.6	17.4	44.4	15.0	3.5
15332	15042	119	Outdoor	II	F	-15.5	16.2	48.3	16.9	3.3
14392	14085	25	Str8	III	H	-16.0	17.0	49.0	17.0	3.4
14404	14100	67	Str9	III	H	-15.7	16.7	48.5	16.6	3.4
14403	14100	67	Str9	III	H	-16.0	15.8	45.8	15.8	3.4
14373	14100	89	Str9	III	H	-15.9	17.0	47.8	16.4	3.4
14335	14078	46	Str9	III	H	-15.7	16.7	47.1	16.3	3.4
15408	15105	44	Str9	III	H	-15.9	17.3	46.2	15.8	3.4
15412	15155	109	Str9	III	H	-15.2	17.8	44.4	15.6	3.3
15400	15155	90	Str9	III	H	-15.2	17.0	43.2	14.9	3.4
15259	15105	43	Str9	III	H	-15.3	17.2	42.7	14.8	3.4
15158	15037	44	Str9	III	H	-16.0	17.0	43.7	15.0	3.4
15165	15037	89	Str9	III	H	-15.9	17.6	44.3	15.6	3.3
15166	15037	89	Str9	III	H	-14.6	18.4	46.1	16.4	3.3
15262	15105	43	Str9	III	H	-15.8	16.5	46.8	16.2	3.4
15167	15037	89	Str9	III	H	-16.0	17.4	45.3	16.1	3.3
15126	15037	66	Str9	III	H	-15.6	16.4	46.0	16.1	3.3
15260	15105	43	Str9	III	H	-15.7	16.6	45.8	15.9	3.4
15326	15105	67	Str9	III	H	-15.7	16.6	46.5	16.2	3.3

Table 1. (Continued.)

Sample (S-#)	Context ID	Square	Structure	Phase	Event	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N
15151	15037	69	Str9	III	H	-16.0	16.6	42.6	14.7	3.4
15169	15037	111	Str9	III	H	-16.0	16.3	46.6	15.7	3.5
1460	13121	56	Str10	III	H	-15.3	16.8	49.0	17.2	3.3
1473	13132	35	Str10	III	H	-15.8	16.5	47.8	16.5	3.4
1559	13170	57	Str10	III	H	-15.0	17.4	47.5	16.6	3.3
1565	13160	56	Str10	III	H	-17.9	15.7	46.9	16.5	3.3
1569	13170	56	Str10	III	H	-16.6	16.0	47.3	16.5	3.3
1592	13170	56	Str10	III	H	-16.2	16.6	49.0	17.1	3.3
15091	15027	20	Str13	III	H	-15.9	15.9	45.8	16.0	3.3
15051	15026	32	Str13	III	H	-16.3	15.4	45.2	15.4	3.4
15058	15026	32	Str13	III	H	-15.9	15.5	44.2	15.5	3.3
15050	15026	32	Str13	III	H	-15.8	16.9	43.3	15.0	3.4
15073	15027	42	Str13	III	H	-16.2	15.8	44.2	15.4	3.3

Comparison with previous studies and site faunal data

Mean $\delta^{13}C$ and $\delta^{15}N$ values for the hair samples from research excavations at Nunalleq presented here are -15.8±0.5 ‰ (1σ) and 16.7±0.6 ‰ (1σ), respectively. These averages, based on the forty-seven new analyses presented here, are similar to those previously reported for hair from the rescue excavations at the site (Britton et al. 2018) and to those reported in an initial pilot study (Britton et al. 2013). The total range of values presented here is also similar to that from previous studies, with $\delta^{13}C$ values in this study ranging from -17.9 ‰ to -14.6 ‰, and $\delta^{15}N$ values range from 15.4 ‰ to 18.4 ‰.

In addition to isotope values previously obtained from human hair from Nunalleq, an extensive faunal isotope dataset has also been generated from animal bone collagen from the site (Britton et al. 2018; McManus-Fry 2015; McManus-Fry et al. 2018). The previously published human hair and faunal bone collagen isotope data from Nunalleq are shown in Figure 2, alongside the new data presented here. Due to differences in the amino acid composition of keratin and collagen, and their anticipated stable isotope ratio offsets, a predicted mean collagen value (±1σ) for human hair from both the rescue (n=57, Britton et al. 2013; Britton et al. 2018) and research excavations (n=47, this study) is also shown (see Figure 2). Bone collagen-keratin offsets were based on O'Connell et al. (2001; +1.41 ‰ and +0.86 ‰ for carbon and nitrogen, respectively).

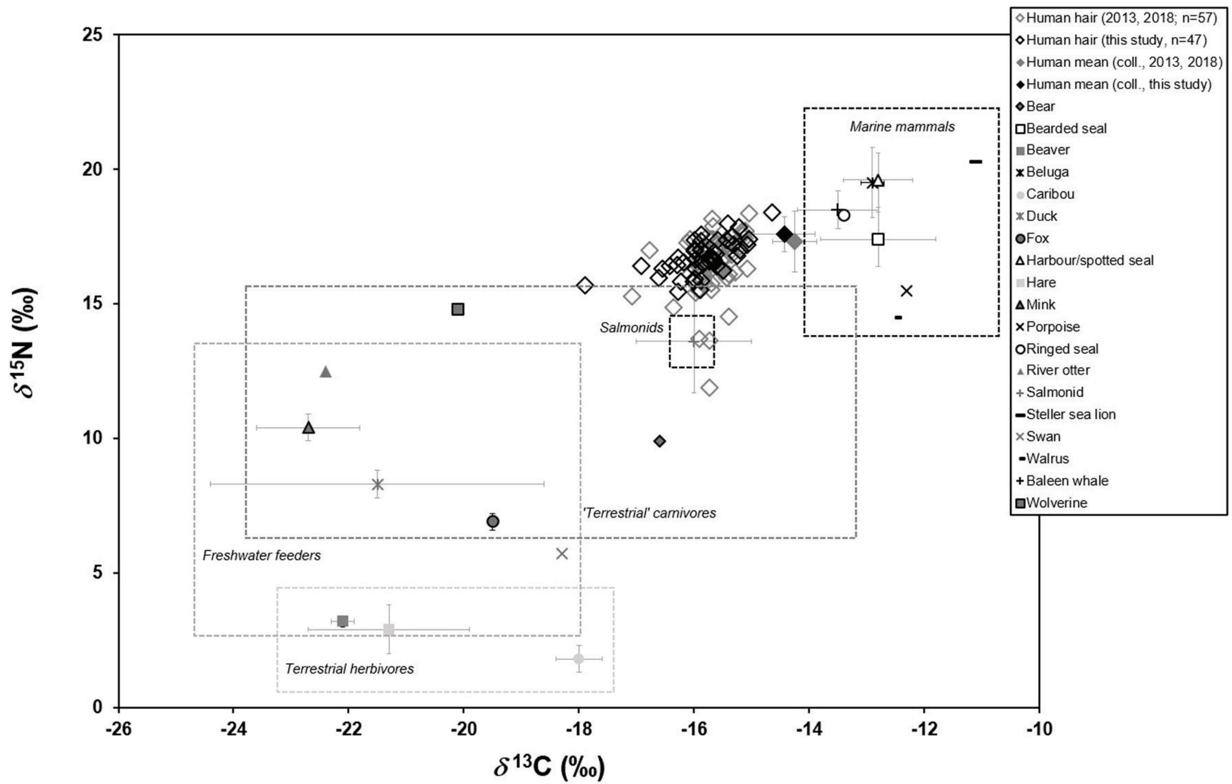

Figure 2. Human hair stable carbon and nitrogen isotope data from both the rescue (2009-2010; Britton et al. 2013; Britton et al. 2018) and research excavations (2013–2015; this study) at Nunalleq, alongside faunal bone collagen isotope data (adapted from Britton et al. 2018, Figure 2). In addition to measured human hair values, a predicted collagen datapoint (mean) is also shown for humans. Analytical precision was ±0.2 ‰ (1σ) or better. Error bars show ±1σ for mean values.

When compared to the terrestrial and marine faunal data from the site, it is likely that during the main period of site use, diet at Nunalleq included high trophic level marine protein (such as pinnipeds), but also incorporated significant contributions from lower trophic level (marine) protein sources. This could have included sea fish or shellfish, or migratory (anadromous) fish such as salmonids, alongside terrestrial protein such as caribou meat. This is consistent with historical and ethnographic accounts of traditional indigenous diet in the Y–K Delta (Barker and Barker 1993; Fitzhugh and Kaplan 1982), and with the results of the previous isotope studies conducted in the area (Britton et al. 2013; Britton et al. 2018). It is probable that caribou, while vital for the acquisition of other resources in the form of antler, would have lesser dietary role than marine resources or salmon (Britton et al. 2018; Masson-MacLean et al. 2019).

Diachronic change in diet at Nunalleq

While the data from the 2009–2010 rescue excavations provide a general picture of diet, the single context recording and extensive program of radiocarbon dating undertaken as part of the research excavations permit insights into potential diachronic dietary variability at the site during its main period of occupation. Samples included in this study include those from the Middle Occupation Phase (III) and the Later Occupation Phase (II).

As shown in Figure 3, mean $\delta^{13}C$ values and $\delta^{15}N$ values for the hair samples from Phase III (middle occupation) and Phase II (most recent occupation) at Nunalleq are almost indistinguishable. However, the range of values in Phase III for both isotopes is greater, ranging from 15.4 ‰ to 18.4 ‰ (~3 ‰) for $\delta^{15}N$, and -17.9 ‰ to -14.6 ‰ (3.3 ‰) for $\delta^{13}C$. In Phase II, interindividual variability is more restrictive, with $\delta^{15}N$ showing a range of 2.1 ‰ $\delta^{15}N$ (from 15.9 ‰ to 18.0 ‰) and $\delta^{13}C$ values ranging by 1.8 ‰ (from - 16.9 ‰ to -15.1 ‰). This suggests diet was more homogeneous (i.e., intragroup dietary variation was lower) during the latest phase (II) of occupation at the site. Furthermore, the lowest $\delta^{15}N$ values exhibited by some individuals in Phase III (e.g., s-15091, s-15051, s-15058, and s-15027) are not observed in Phase II. In light of the associated (marine) $\delta^{13}C$ values, it is unlikely that the lower $\delta^{15}N$ values are due to an increased consumption of terrestrial protein (such as caribou meat) but are instead lower consistent with a diet that included a greater proportion of lower trophic level marine/ anadromous protein, such as salmon. The higher $\delta^{15}N$ values demonstrated by other individuals in Phase III, along with their (slight) enrichment in ^{13}C, suggest a greater inclusion of higher trophic level marine protein, such as marine mammal meat. These data indicate that, while diet was broadly similar through time at Nunalleq, dietary variability was greater in Phase III than in the later Phase II, and that the exploitation of certain lower trophic level foods, such as salmonids, may have decreased. This correlates with the zooarchaeological evidence from Phase III and Phase II, which demonstrate a decrease in fish between the middle and latest occupations at the site.

Spatial variability in diet at Nunalleq

The greater interindividual isotope variation observed in Phase III in comparison to the later occupation phase (Phase II) suggests some differences in diet within the resident population of Phase III. These differences likely reflect the greater proportion of lower trophic level foods such as salmonids in the diet of some, and/or the increased consumption of foods such as marine mammal meat amongst others. The comparison of isotope ratios of human hair across the different structures and 2 x 2 metre excavation squares at the site, particularly in Phase III, may provide greater insight into the nature of this dietary variability (see Figure 4 and Figure 5).

Analysis by *t*-test does not suggest any significance difference in ^{15}N enrichment between structure-groups (1 and 2) in Phase II (t=0.62094; p=0.547). However, as shown in Table 1 and Figure 4, many of the individuals exhibiting the lowest or the highest $\delta^{15}N$ values are found in structure 13 and structure 9, respectively, both during Phase III. One-way ANOVA shows a significant difference in ^{15}N enrichment between the structures in Phase III (F=6.01; p=0.007). *Post hoc* Tukey-Kramer test for all pairwise comparison of structures 9, 10, and 13, reveals a significant difference in $\delta^{15}N$ values between structure 13 and structure 9 (p=0.006). The spatial distinctions in mean ^{15}N-enrichment across squares and associated structures in Phase III are also apparent in Figure 5, highlighting the increased dietary variability in Phase III (compared to Phase II). Figure 5 also demonstrates lower $\delta^{15}N$ values are mostly found in a restricted area of the site during Phase III, small side room Structure 13.

These temporal and spatial isotope data from Nunalleq bring nuance to previous palaeodietary isotope research at the site (Britton et al. 2013; Britton et al. 2018), and may suggest diachronic dietary shifts during the course of the Little Ice Age over a period of less than one hundred years. The decreased emphasis on lower trophic level marine/anadromous protein in Phase II, compared to Phase III, echoes the results of zooarchaeological research at the site (Masson-MacLean et al. 2019). While salmon invariably continued to be an important subsistence resource overall and was still likely the dominant protein source (as indicated by previously published mixing models of similar mean isotope data from Nunalleq; see Britton et al. 2018), the combination of isotopic and zooarchaeological evidence from Phase II may suggest a decline in this major subsistence resource during the Little Ice Age, a well-documented period of harsher climatic conditions in Alaska and at Nunalleq specifically (Forbes et al. 2019; Mann 2007). In this sense, these data may provide indirect evidence for the flexibility inherent in the tripartite subsistence strategy (salmon, seals, caribou) commonly associated with Thule-era Arctic (and

Subarctic) groups, and their resilience in the face of environmental instability and inclemency during the Little Ice Age (Betts 2008; Masson-MacLean et al. 2019). However, the spatial trends highlighted in Phase III may suggest a change not only in resource availability and subsistence activity of the site, but perhaps also in social organization at the site during the seventeenth century.

Traditional subsistence practices and cuisine are well documented amongst the Arctic's Indigenous peoples, and in Alaska in particular, with the relatively late colonial contact likely accounting for the rich and intact food histories of Inupiat and Yup'ik culture (Spray Starks 2007, 42). Today, and in recent history, traditional subsistence diets in the Y–K Delta incorporate a

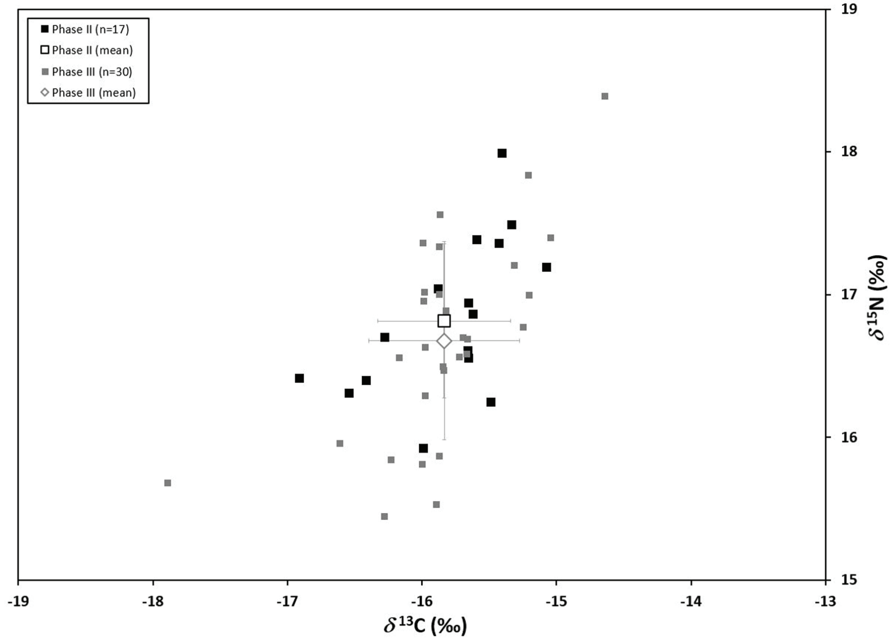

Figure 3. Human hair stable carbon and nitrogen isotope data from the research excavations at Nunalleq, comparing all data from the middle (Phase III) and most recent (Phase II) periods of occupation. Analytical precision was ±0.2 ‰ (1σ) or better. Error bars show ±1σ for mean values.

wide variety of resources, including marine mammals, salmonids, caribou, sea birds, marine fish, small mammals, and other animals, as well as berries and limited other vegetative foods (Barker and Barker 1993; Fitzhugh and Kaplan 1982; Spray Starks 2001). Sharing is considered a very important aspect of traditional subsistence practices amongst many Indigenous Arctic cultures (see references in Gombay 2009), including Yup'ik communities (Fienup-Riordan and Rearden 2012, 35–38). Ethnographic accounts, for example from Nelson Island, do however also point to differences in food sharing and distribution between Yup'ik families and non-relatives for certain species, or even preferred parts of certain species, such as seals or walrus ("a hierachy of parts," Fienup-Riordan 1983, 135). The ethnographically documented *qasgi* or man's house, structured around social position, also

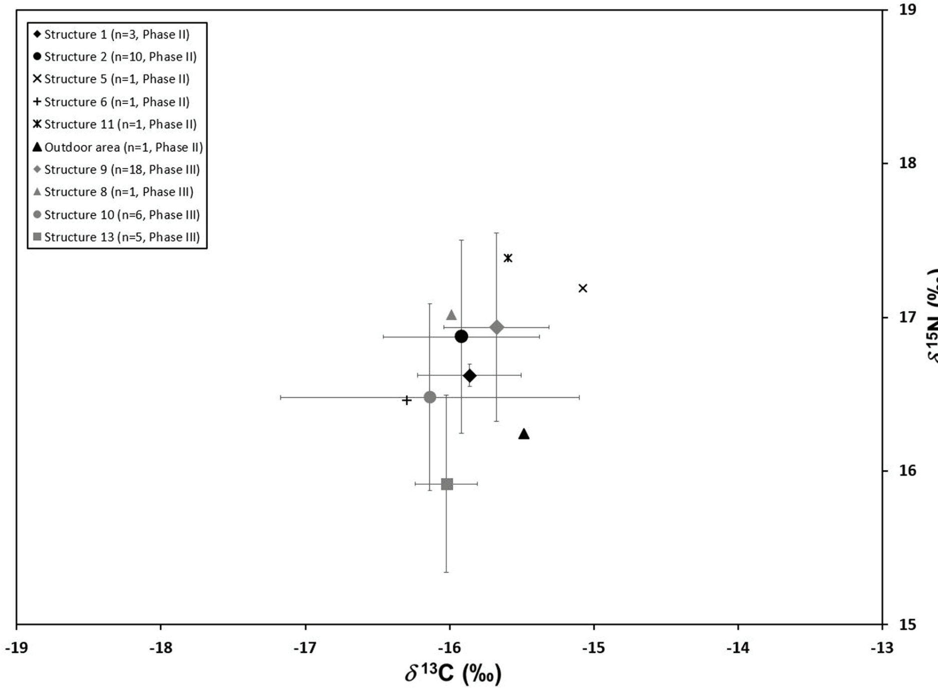

Figure 4. Stable carbon and nitrogen isotope ratios of human hair from Nunalleq by structure and phase. Mean values are shown where multiple samples were obtained from different structures. Analytical precision was ±0.2 ‰ (1σ) or better. Error bars show ±1σ for mean values.

evidences social distinctions expressed through physical means in recent historic Yup'ik culture. It is noteworthy, however, that food was not shared in such contexts; daughters and wives brought personal meals to the *qasgi* (Fienup-Riordan and Rearden 2012, 17). However, relatively little is known about the social aspects of subsistence, foodways, and cuisine in the precontact Y–K Delta, or indeed intragroup relations more broadly prior to the arrival of Euro-Americans. Epidemics of the mid-1800s (which killed as much as 60 per cent of the Indigenous population) are thought to have damaged not only regional social distinctions but also social groups and patterns of intragroup relations in the Y–K Delta (Fienup-Riordan and Rearden 2012, 16). The dietary variability observed in this study during the middle occupation of the site might provide tentative evidence of diversity in precontact intergroup relationships through time in the Y–K Delta, at least in terms of differential access to food resources. Given the current lack of information about the individuals from which the hair samples originated (such as sex, age class, etc.), the extent to which such identities influenced dietary choices and/or access to resources at Nunalleq is not known. The genetic screening of samples for sex determination is ongoing and may, at least in part, illuminate the relationship between diet and this aspect of sociobiological identity (if any). It should be noted, however, that, given the inability to differentiate individuals definitively in the current study, it is also possible that some variability observed represents intra-annual (seasonal) or supra-annual dietary change in the same person. Finally, while the variations observed during the occupation of the site between Phase III and Phase II may relate to contemporary climatic changes, which may have influenced resource availability, concurrent socio-political factors in the region (beyond Euro-American contact) must also be born in mind. The precontact period in the Y–K Delta was characterized by a series of intragroup conflicts, known as the Bow and Arrow War Days (Kurtz 1985). While the origins and nature of these tensions are poorly understood, this period brought coastal and riverine groups into conflict, and its relationship to, or influence on, regional resource use and subsistence is not known (Fienup-Riordan and Rearden 2012, 2016). The occupation in Phase II ends abruptly in a burning event and destruction, and—as previously speculated—it may have been the location of Nunalleq, with its ready access to both coastal and riverine resources during the unpredictable conditions of the Little Ice Age, that ultimately lead to its destruction (Masson-MacLean et al. 2019). The ways in which the dietary changes observed at Nunalleq during the seventeenth century relate to these changes must be further investigated.

This research evidences both diachronic and spatial variability in diet at the Nunalleq site for the first time and provides a more detailed insight into the nature of precontact diet in the Y–K Delta during the Little Ice Age and the Bow and Arrow War Days. However, the integration of stable isotope and zooarchaeological data with other types of evidence from the site is needed to better understand the nature of dietary change between Phase III and Phase II, and, in particular, the spatial variability observed in the Phase III isotope data. The spatial plotting of finished artefacts found in different parts of the site (such as wooden objects, lithics, and pottery), alongside raw materials, blanks, preforms, and debitage, will be particularly useful in determining the activities undertaken across different areas of the site. Such information can inform the identity and status of the main users of different structures and areas within them (e.g., as in the Canadian Northwest Coast; see Coupland,

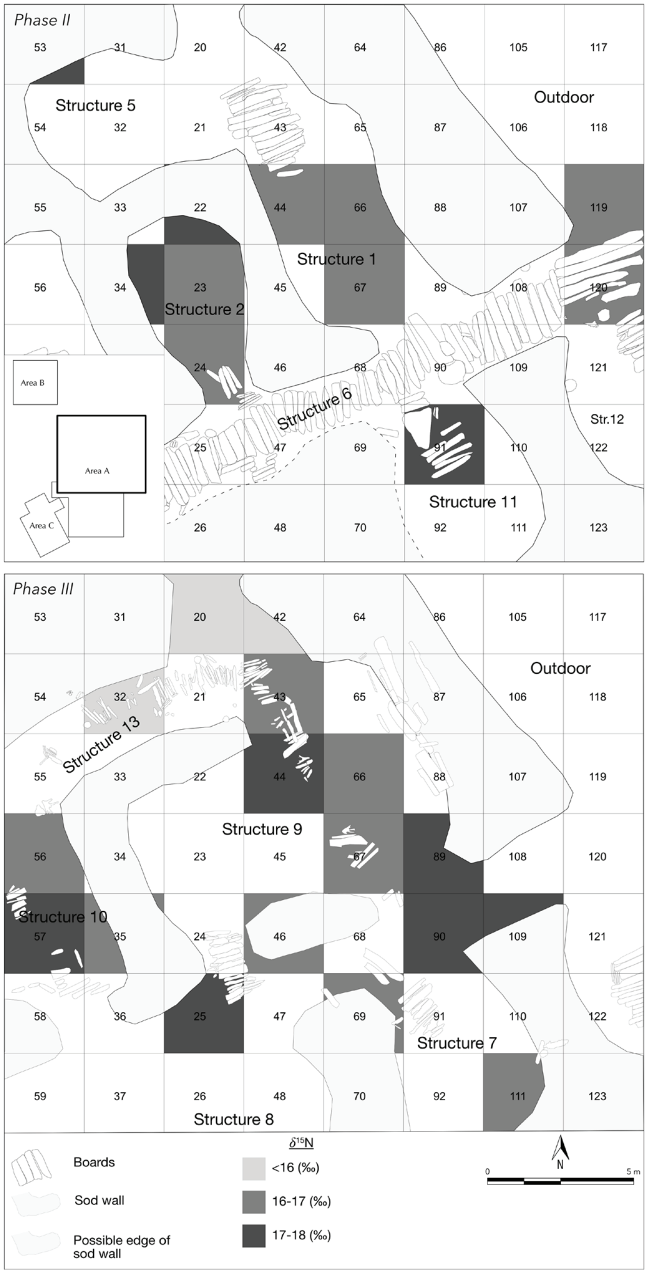

Figure 5. Mean nitrogen isotope values of human hair from the middle (Phase III) and most recent (Phase II) periods of occupation at Nunalleq by square, grouped in three categories ($\delta^{15}N$ = <16 ‰, 16–17 ‰, and 17–18 ‰). Position of boards and sod walls, along with structure identifiers are also shown.

Clark, and Palmer 2009; Grier 2016). The analysis of plant microfossils and insects from Nunalleq could also provide important useful comparative bioarchaeological datasets for inferring use of space/activities at the site. The determining of biological sex in hair samples would also provide greater insight into the individuals studied, use of space at the site, and the nature of the interpersonal dietary variability observed in Phase III. Although the hair from Nunalleq is cut (lacking roots), previous research has demonstrated it is possible to obtain the whole genome, including the sex chromosomes, from hair shafts (Rasmussen et al. 2010; Rasmussen et al. 2011), particularly in cases of good preservation (such as permafrost). Finally, the incremental isotope analysis of longer hair strands, in particular from structure 9 and structure 13, will provide additional seasonal insights into contemporary diet and may serve to further emphasise (or indeed provide countering evidence of) interindividual dietary variation during Phase III.

Conclusions

Following on from initial research at the site on materials from the rescue excavations, this study provides the first evidence of site-spatial differences in diet at Nunalleq during a single phase, as well as dietary changes during the period of occupation. Alongside zooarchaeological data, this research permits a more detailed insight into the nature of precontact diet in the Y–K Delta during the seventeenth century, a period of climatic and socio-political instability. Although isotope data are similar in both Phase III (cal AD 1620–1650) and Phase II (cal AD 1640–1660), there is more variation during Phase III between different samples. The variation in isotope ratios most likely reflects dietary variation, probably relating to the relative contribution of salmonids versus higher trophic level marine mammal protein to the diet during the period represented by the cut strands of hair. Although sample size is relatively small and it is not yet possible to differentiate between individuals (i.e., some hair samples could represent duplicates from the same individuals, potentially from different periods/seasons of hair growth), spatial analysis of isotope data does suggest these differences vary across the different activity areas and structures at the site. This may indicate a link to use of space at the site, and/or hint at possible social differentiation in diet during Phase III. In the final occupation phase (Phase II), isotope data are more homogeneous and may be indicative of an increased consumption of higher trophic level marine foods at this time. While the influence of the Little Ice Age on wild foods in the region is uncertain, and the relationship between the Bow and Arrow War Days and the distribution of (and access to) resources is not known, it is possible that either (or both) of these factors may have led to the changes in diet (and possibly even social organization) evidenced in the isotope dataset. Comparison with other data, including material culture from the site, as well as the results of other bioarchaeological analyses at the site, will be essential in understanding these differences and further illuminating precontact lifeways in the Y–K Delta.

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