ARTICLE IN PRESS

Quaternary International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Pre-contact adaptations to the Little Ice Age in Southwest Alaska: New evidence from the Nunalleq site

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A R T I C L E I N F O

Keywords:
Arctic
Archaeology
Zooarchaeology
Technology
Isotopes
Diet
Subsistence

A B S T R A C T

The reconstruction of diet, subsistence strategies and human-animal relationships are integral to understanding past human societies, adaptations and resilience - especially in the circumpolar Arctic. Even in relatively recent periods, climatic excursions may have posed specific challenges for hunter-gatherer groups living at latitudinal and climatic extremes, and archaeological research in Arctic North America is increasingly looking to better understand the impact of past climate change on human groups. Here, through a unique multi-proxy approach (zooarchaeology, bone technology and stable isotope analysis), we explore human subsistence strategies, adaptation and resilience at Nunalleq, a recently excavated pre-contact Yup'ik coastal site in southwest Alaska. The main phase of occupation of the site (16th-17th centuries AD) corresponds with one of the coolest periods of the Little Ice Age – a climatic interval from the early 14th century through the mid-19th associated with global and more localised cooling events. The analyses reveal a subsistence strategy centred around the exploitation of three major resources, including salmon, marine mammals and caribou, supplemented by secondary resources such as birds and medium-sized mammals. This tripartite resource base (salmon, marine mammals, caribou) is similar to that seen at other Thule-era sites in Alaska and likely permitted a flexibility in resource use in the face of changes in resource availability (and competition over resources) during the Little Ice Age. Comparison of the different datasets, however, reveals variability and nuance in the use of animals for both dietary and broader subsistence needs. While caribou represent a vital and heavily-exploited resource at Nunalleq (evident from both the zooarchaeology and the bone technology), they did not represent a key dietary resource (indicated by stable isotope data). Instead, caribou played an integral and key part as a major source of raw material, especially antler, in order to manufacture the necessary acquisition technology to exploit primary coastal resources.

1. Introduction

Arctic regions have been near-continuously inhabited by humans for millennia (Rowley-Conwy, 1999; Hoffecker, 2005; Serreze and Barry, 2005), despite their extreme environments and unpredictable, highly variable, conditions. In this sense, Arctic environments have borne witness to the zenith of human adaptation and resilience, past and present (Krupnik, 2000; Huntington et al., 2017). In addition to the effects of long-term global climatic change, over recent years short-term climatic excursions ('bad years' and localised climatic events) have had a marked influence on the subsistence patterns of native communities (e.g. Callaway et al., 1999; Craver, 2001). Given that similar climatic scenarios occurred throughout the Holocene, understanding the manner in which pre-contact populations responded to changes in environmental conditions has been a growing area of interest in Arctic archaeological research (Mason and Gerlach, 1995; Darwent, 2004;

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https://doi.org/10.1016/j.quaint.2019.05.003
Received 9 November 2018; Received in revised form 30 March 2019; Accepted 2 May 2019

West, 2009a; 2009b; Woollett, 2007; Sørensen, 2010; Grønnow et al., 2011; Desjardins, 2018). Most previous studies focused on human adaptive strategies during the Little Ice Age (LIA; 1350–1850 AD), a period of rapid cooling and environmental unpredictability (Mann, 2002). Archaeological studies have demonstrated how people responded to climatic shifts across the Arctic, including changes in settlement patterns and subsistence strategies, with responses often being loci-specific rather than pan-Arctic. Few studies, however, have taken place in South-West Alaska.

Present-day environmental change is not only having a major impact upon available resources in the Arctic and the people who depend on them, but is also serving to destroy the record of their past lifeways in the circumpolar North. Today, arctic archaeological sites are under constant threat of coastal and riverine erosion, melting permafrost, marine inundation and increasing storm surges that are resulting in the loss of a uniquely well-preserved archive (Murray et al., 2011). This is particularly true for South-West (SW) Alaska, and the Yukon-Kuskokwim Delta (Y.-K. Delta), where archaeological sites are heavily damaged by coastal and fluvial erosion (VanStone, 1984a). This, combined with logistical and transport difficulties, has impeded detailed archaeological research in the region, resulting in a knowledge gap in Arctic prehistory where comparatively little is known of pre-contact life in the Y.-K. Delta (VanStone, 1984b; 1984a; Shaw, 1998).

The recent discovery of the late pre-contact site of Nunalleq, located close to the village of Quinhagak in the Y.-K. Delta (Fig. 1) and its subsequent large-scale and ongoing excavation (Britton et al., 2013; McManus-Fry, 2015; Ledger et al., 2018; Masson-MacLean, 2018), provides a unique opportunity to elucidate pre-contact lifeways in this region. Whilst the site appears to have been occupied for a period of up to 300 years (late 14th/15th to mid-late 17th centuries AD), the densest occupation levels date to the early - mid-17th century (Ledger et al., 2018), a time period coinciding with one of the coldest phases of the LIA (the Maunder Minimum). Subsistence strategies and technologies are the cornerstones of hunter-gatherer resilience (Solich and Bradtmoller, 2017), and the large and well-preserved assemblages of *in situ* artefacts and bioarchaeological materials from Nunalleq offer the near-unique possibility to explore pre-contact lifeways in the Y.-K. Delta and human adaptation during the LIA in SW Alaska.

In this study, we employ a range of methodological approaches to reconstruct subsistence strategies at the height of the LIA in SW Alaska. We combine zooarchaeological analyses with the examination of bone technology as a means of exploring animal exploitation. These tandem facets of subsistence strategy are analysed and interpreted alongside localised climate records (Forbes et al. in review) and previously-published human palaeodietary isotope data from the site (Britton et al., 2013, 2018) to infer the exploitation of animal resources (from hunted animal to primary and secondary product use), during the LIA. Our aim is to illuminate foodways at the site during this crucial period and to more closely examine human-animal relationships amongst the pre-contact populations of the Y.-K. Delta.

2. Background

2.1. Site location and environment

The Nunalleq site (GDN-248) is located on the shores of the Kuskokwim Bay between the Kanektok and Arolik rivers, approximately 5 km south of the modern Yup'ik village of Quinhagak (Fig. 1). The Y.-K. Delta is an area of coastal wet tundra, but also includes interior boreal forests, wetlands and areas of higher ground, and is bordered by the Akhlun Mountains to the south and east. The vegetation is primarily subarctic tundra supporting wet tundra plant communities of sedge mats, moss, and low-growing shrubs (Raynolds et al., 2006). The resource-rich, but seasonal, landscape features some of the largest

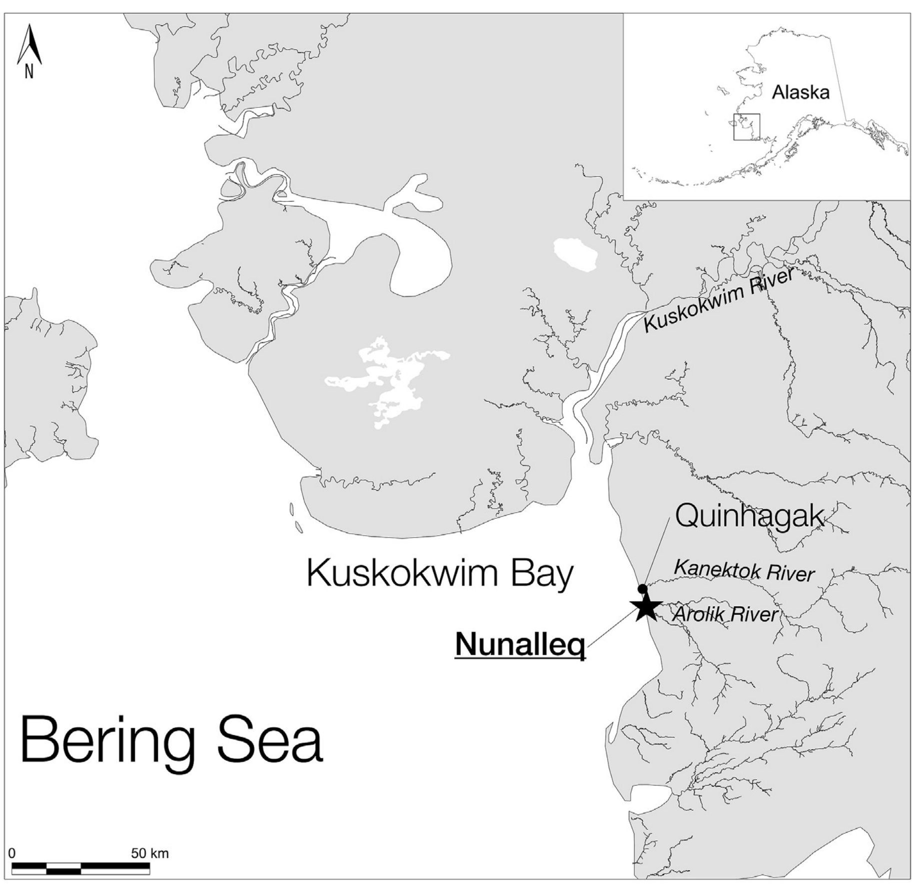

Fig. 1. Site location map of the Nunalleq site.

aggregations of waterbirds in the world and large runs of anadromous fish. Year-round residents include certain birds such as ptarmigan or owls, fur-bearing animals such as otters, beavers and small mustelids and predators such as wolves and foxes (Alaska Department of Fish and Game, 2006; US Department of the Interior, 2004). The riparian environment and migrating salmon also attract bears, and caribou are found across the tundra seasonally. The coastlines and estuaries provide feeding grounds for small cetaceans and pinnipeds (Alaska Department of Fish and Game, 2006). Sea-ice formation on the Bering Sea constitutes one of the other major physical elements of the region. Unlike the Arctic Ocean, the Bering Sea is ice-free during the summer (Wendler et al., 2013) and extends along the coast between November and March or April (National Research Council, 1996, 41; Wang et al., 2009, 7; Wendler et al., 2013).

The modern climate of southwest Alaska is Arctic and continental with cold and snowy winters and cool damp summers (Kottek et al., 2006), with average annual temperatures ranging from −4 °C to +3 °C (Alaska Department of Fish and Game, 2006). The site of Nunalleq was occupied during the Little Ice Age (14th - 19th centuries AD), a period marked in North America and Alaska by generally colder conditions, increased snowfall, reduced summer temperatures and the expansion of sea-ice beyond its current extent - including in the Bering Sea (Pielou, 1992; Loso, 2009; Schiff et al., 2009; Miller et al., 2010; Mahoney et al., 2011; Lehner et al., 2013). Recent paleoenvironmental research has demonstrated that people living at Nunalleq did indeed experience colder conditions than today, with lower average summer temperatures by at least 1.3 °C (Forbes et al. in review). The main period of occupation of the site coincided with one of the most inclement phases of the LIA, marked by the greatest advances of glaciers and increased storminess in Alaska (Mason and Gerlach, 1995) and by a period of climatic and social unrest across the whole of the Northern Hemisphere (Parker, 2013).

2.2. Archaeology of the Y.-K. Delta

The earliest occupations in the Y.-K. Delta have been attributed to the Norton culture around 2500 years ago, though there is evidence of Arctic Small Tool occupations in the Naknek drainage in the northern Alaskan Peninsula (VanStone, 1984a). From approximately AD 1000, the Thule culture spread to the Y.-K. Delta, replacing or incorporating people of the earlier Norton Tradition (Dumond, 1987; McGhee 1996). The Thule (referred to as Western Thule in Alaska) were coastal people who exploited a variety of resources primarily focused on marine mammals, large terrestrial herbivores and fish. They appear to have mastered the use of (sled) dogs found across the Arctic from Alaska to Greenland by the end of the first millennium AD (Sheppard, 2004).

Today the Y.K. Delta is the heartland of the Central Alaskan Yupiit, of the Eskimo/Inuit-Aleut language group (Krauss et al., 2011; Dallmann and Schweitzer, 2015), likely descendants of the Thule (Raghavan et al., 2014). There is a rich post-contact ethnographic record documenting Yup'ik culture, but pre-contact lifeways in the region are more difficult to discern, not least due to the lack of archaeological research in the area. The consensus among scholars is that during the prehistoric period, southwest Alaska was probably more influenced by cultures from the Pacific Northwest coast than other regions further north that were occupied by Inuit/Eskimo groups, in particular with their more complex forms of social and ceremonial life (VanStone, 1984b 208). Amongst the historic Yup'ik, subsistence was focused on the exploitation of maritime and inland resources. People lived in permanent villages, but they also moved between seasonal hunting and fishing camps. Coastal communities primarily hunted marine mammals (particularly seals), with excursions to the tundra to hunt caribou and to river mouths and rivers to harvest salmon. The assumption remains that prehistoric subsistence in the Y.-K. Delta was likely similar to their post-contact counterparts. By the arrival of the first ethnographers, the Fur Trade and Christianity had already impacted Yup'ik communities, influencing subsistence activities along with many other aspects of life (VanStone, 1984b, 207–208, 1984a: 229). Furthermore, the climatic excursions of the late Holocene - including the Medieval Warm Period and Little Ice Age - may well have influenced the geographical and seasonal distribution of resources and their abundance, influencing subsistence activities (Mason and Gerlach, 1995; West, 2009a). With access to key resources potentially restricted, increased competition for those resources has even been linked to a period of regional warfare in the Y.-K. Delta, known as the 'Bow and Arrow War Days' (Kurtz, 1985). While the origins of the conflict are poorly understood, this tension between riverine and coastal groups was part of a wider pan-Alaskan period of inter-group violence (Funk, 2010; Fienup-Riordan and Rearden, 2016) that finally ceased with the arrival in the region of Russian explorers and traders during the 1840s.

3. Materials and methods

All materials included in this study originate from the Nunalleq site ("*Old Village*" in *Yup'ik*). Over the past decade, the site has been the subject of both rescue (2009–2010) and research (2012 onwards) excavations, led by the University of Aberdeen and the local native corporation - Qanirtuuq Inc. Investigations at the site have revealed the remains of a semi-subterranean sod and timber dwelling (Areas A, C and D; see Figs. 2 and 3), occupied primarily between AD 1570 and 1675 (Ledger et al., 2016, 2018), along with refuse deposits (Area B). To date, at least three occupation phases have been identified at the site in Area A (Fig. 2; see Ledger et al. (2018)): Phase II represents the latest occupation at the site, beginning somewhere in the interval AD 1640–1660, prior to the site being attacked (likely during the Bow and Arrow War Days) and then finally abandoned. Several rooms were identified, along with a main passageway leading to them (evidenced by a well-preserved boardwalk) and a possible entrance at its eastern extremity. Phase III is an earlier occupation, which began in the interval AD 1620–1650 and lasted for up to 35 years, during which the layout of the dwelling was very similar to Phase II, though appears to cover a greater area and include a bigger central room in lieu of smaller internal spaces. Phase IV has been identified as a possible older dwelling, existing prior to a remodelling event and later occupation phase, but has not yet been fully excavated. Bayesian modelling suggests that the beginning of Phase IV dates from between AD 1570 and 1630 (Ledger et al., 2018).

The preservation of most remains at the site is exceptional due to the presence of permafrost in the Y.-K. Delta (Black, 1958) and waterlogged soils. This has led to the recovery of an extensive assemblage of material culture (*i.e.*, more than 60,000 items – many of them organic) and a large bioarchaeological collection that included bones (*i.e.*, 30,000 fragments), animal fur and human hair, as well as plant and insect remains, providing detailed evidence of human diet and past living conditions at the site (Britton et al., 2013, 2018; Forbes et al., 2015). The recovery of zoomorphic wooden masks, animal bone carvings, hunting and fishing equipment and animal figurines attest to the central economic and cultural role animals played in pre-contact Yup'ik society. The zooarchaeological assemblage and technological bone and antler material analysed for this study originates from the 2012 to 2015 field seasons.

3.1. Analysis of the vertebrate remains

The animal bone was recovered from both hand-collecting and on-site dry-screening using a 1.27 cm (1/2 inch) mesh. In addition, bulk samples from house floors were taken for the recovery of small bones etc. (after Dobney et al., 1992) and wet-sieved to 3 mm. The Nunalleq vertebrate assemblage is stored at the University of Aberdeen. The sample presented here comprises 9273 bone fragments, excluding unidentifiable small fragments of limited or no interpretative value. The sample originates from Areas A, B and D (Fig. 3) and does not include

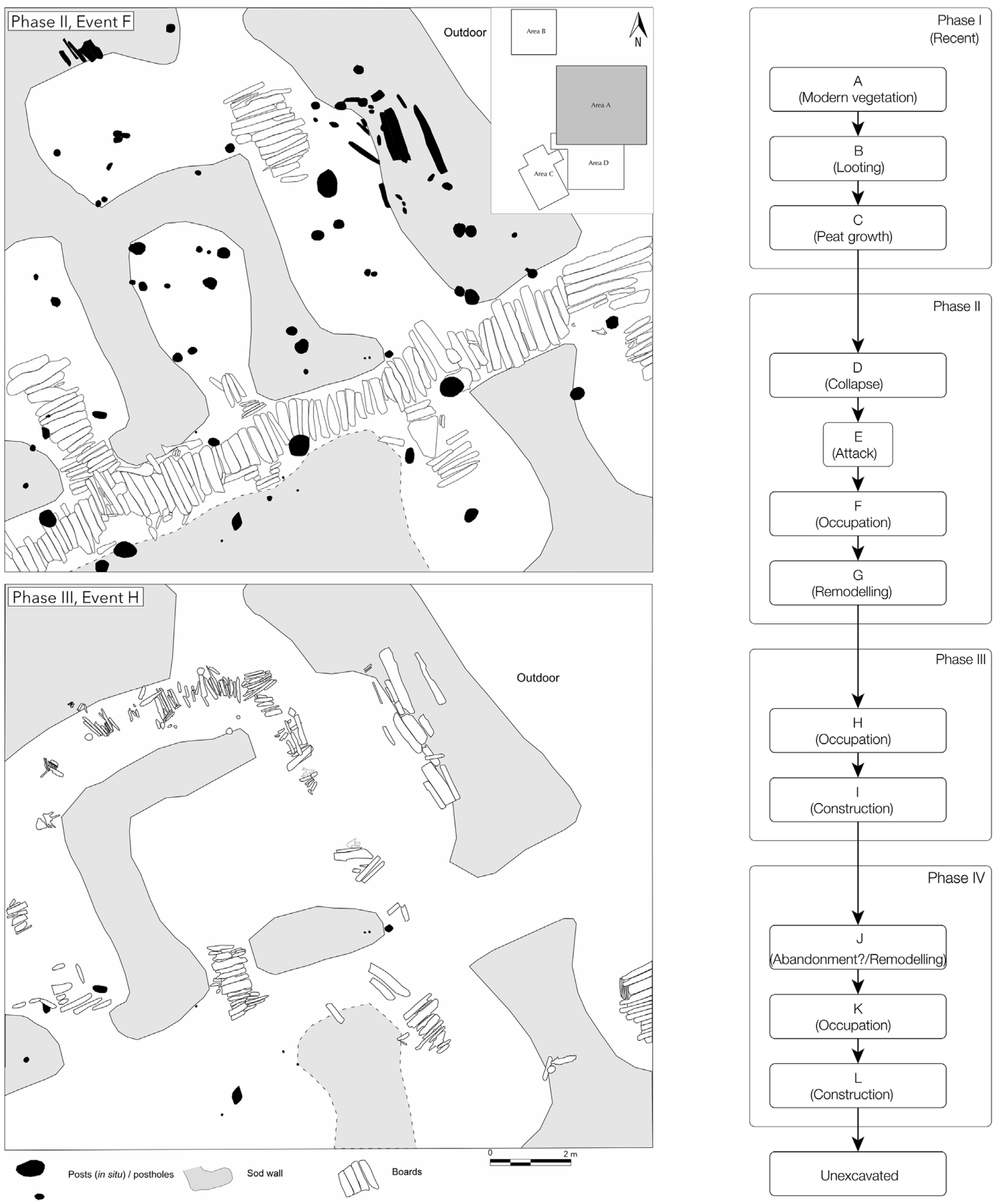

Fig. 2. Site plan of Nunalleq showing occupation phases II & III and schematic stratigraphic diagram.

material from the 2009–2010 rescue excavations in Area C nor material from the 2017-2018 field seasons. . Based on surface preservation, most of the assemblage was in excellent condition and the presence of otherwise fragile bird bones was also indicative of a well-preserved assemblage (Serjeantson, 2009).

Identifications of the vertebrate remains were made using modern comparative reference collections (O'Connor, 2000; Reitz and Wing, 2008) held at the University of Alaska Museum of the North in Fairbanks (UAMN) for pinnipeds and cetaceans; the Muséum National d'Histoire Naturelle in Paris (MNHN) for birds; the National Museum of Scotland (NMS) in Edinburgh for terrestrial and marine mammals; and from the University of Aberdeen for other fish, birds and medium-sized mammals. The osteological identifications were supplemented by the use of illustrated and photographic guides including Smith (1979), Gilbert (1990) and the Virtual Zooarchaeology Arctic Project database (Betts et al., 2011) for mammals, Cohen and Serjeantson (1996) for avian remains combined with references to Armstrong (1995) for the geographic distribution of Alaskan birds, and Cannon (1987) for fish remains.

3.2. *Bone technology*

To better understand the role of vertebrate resources in technology at the site, the use of bone, tooth/ivory and antler. was also assessed as part of this study. This included the identification and analysis of a large sample of finished objects (e.g. tools, weapons and other accessories) manufactured from bone and related materials (but also the assessment of blanks, preforms and debitage (n = 1320)), as well as the

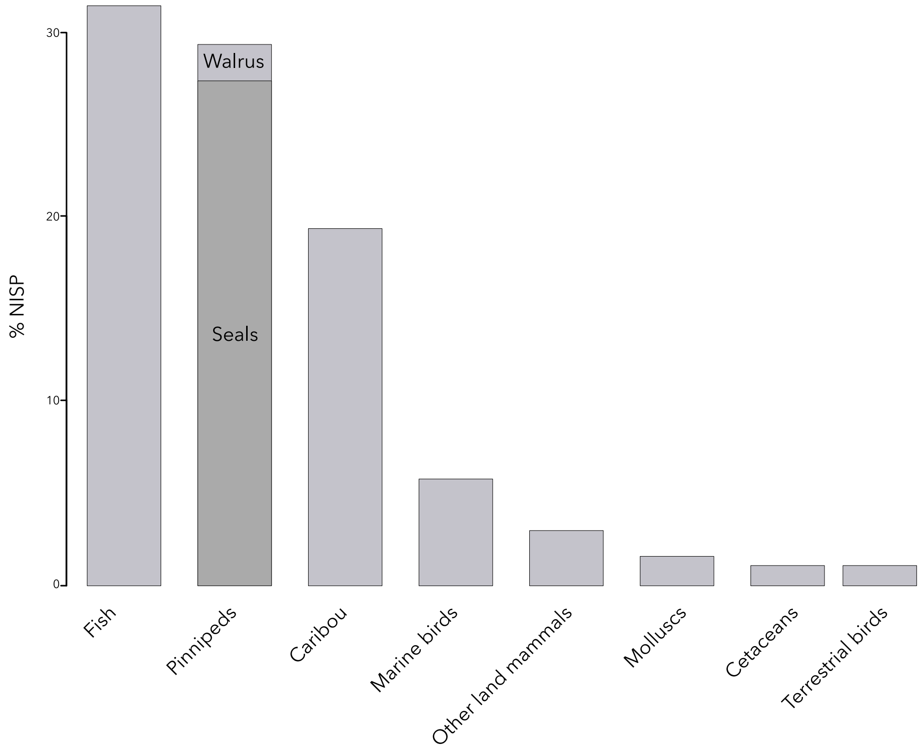

Fig. 3. Histogram showing the different wild animal resource categories exploited at Nunalleq (excluding domestic dog).

faunal assemblage itself in order to identify modifications of associated raw materials. This approach to technology, from raw materials to finished object, uses the concept of the *chaîne opératoire* (Leroi-Gourhan, 1964) to map the reduction sequence as raw material is shaped to produce a finished tool, and provides greater insight into manufacture than analysis of the finished object alone. For example, understanding the production pathway can illuminate factors behind raw material selection and the constraints related to the use of specific materials/technological approaches. Furthermore, relating such factors to the wider zooarchaeological assemblage and to diet (through integrating zooarchaeology with e.g. human stable isotope data) helps contextualise material selection within the framework of broader economic and cultural choice. The identification and characterization of technologies related to subsistence has also the potential to inform on human adaptations to stress, whether of environmental or of other origin, as hunter-gatherer toolkit complexity and diversity appear to be related to the risk of resource failure and shifts in subsistence strategies (Torrence, 1983: 21; Collard et al., 2005). In order to explore this particular aspect of technology at Nunalleq, a detailed diachronic and technological analysis of the osseous material would be necessary, which is beyond the scope of this study. Here, our inclusion of preliminary data from the osseous industry aims to provide a more complete picture and understanding of animal use at the site as technological analyses can also infer on the differential us e and availability of raw materials, something that is particularly useful at Arctic sites (Corbin, 1975; Lemoine, 2005; Houmard, 2011, 2016, 2018). All artefacts have now been returned to the newly-established Nunalleq Culture & Archaeology Center in Quinhagak.

4. Results and data interpretation

4.1. Species representation

Fish (27.9% NISP) and marine mammals (27% NISP) dominated the Nunalleq faunal assemblage in terms of numbers of identifiable fragments, followed by caribou (17.2% NISP) and domestic dog (16.9% NISP). Birds (6.6%) and other terrestrial mammals (2.7% NISP) and bivalves (1.3%) comprise the remaining taxa (Fig. 3; Table 1). Whilst not all fish remains were identified to genus/species, initial assessment, not surprisingly, underscores the predominance of salmonid (*Oncorhynchus* spp.) vertebrae (81.9% fish NISP) and thus a quasi-absence of other fish species. Though not analysed at this stage, remains from other fish species are present in bulk samples but in low frequencies. Among marine mammals (93.6% marine mammal NISP), true seals (Phocidae) are far more frequent than larger taxa such as beluga or walrus. However, the low representation of these species may be related to butchery at the kill site and transport decisions given the relatively large size of these animals (Betts, 2016). Small ice seals, including ringed and spotted seal and the larger bearded seal, were also identified in the assemblage. The near-absence of large cetaceans is likely either a direct result of whales avoiding the shallow waters and the sea-ice of the Kuskokwim Bay or (again) transport decisions linked to the large size of carcasses. The data for caribou presented in Table 1 excludes the vast amounts of antler recovered from the site. Bird remains included mainly migratory waterfowl and other marine birds, while other mammals identified included primarily mustelids and beaver. Bear and wolf were represented by a few elements. In total, at least 25 taxa were identified suggesting a wide variety of species were available and that people at the site benefited from a certain degree of ecological stability and abundance (Desjardins, 2018).

A preliminary diachronic analysis of possible differences in taxonomic representation between Phases II & III was undertaken using material from selected house floors in Area A (Fig. 4). Results show an apparent decrease in fish remains between the two phases, with fish appearing less frequent in the later Phase II. Inversely, caribou, dog and marine mammals all appear to be better represented in Phase II in comparison to earlier Phase III, although the rank order of resources does not change. Marine mammals were less well represented than caribou in house floor deposits, which differs from the overall taxonomic representation at the site. This may be the consequence of species-specific discarding practices influencing faunal composition across the site (Friesen and Betts, 2002), or perhaps related to different species

Table 1
List of taxa identified in the faunal assemblage.

	Taxon	NISP	% NISP	MNI	% MNI
Caribou[a]	*Rangifer tarandus*	1593	17.2%	31	10.2%
Domestic dog	*Canis familiaris*	1567	16.9%	59	19.5%
Fox	*Vulpes* sp.	67	0.7%	11	3.6%
Beaver	*Castor canadensis*	50	0.5%	8	2.6%
Hare	*Lepus* sp.	19	0.2%	2	0.7%
Lemming/vole	Arvicolinae	18	0.2%		
Porcupine	*Erethizon dorsatum*	18	0.2%	4	1.3%
American mink	*Neovison vison*	13	0.1%	6	2.0%
American marten	*Martes americana*	12	0.1%	4	1.3%
Wolf	*Canis lupus*	11	0.1%	1	0.3%
Bear	*Ursus* sp.	11	0.1%	1	0.3%
Dog/Fox	Canidae	9	0.1%		0.0%
Otter	*cf. Lutra canadensis*	8	0.1%	4	1.3%
Muskrat	*Ondatra zibethicus*	7	0.1%	3	1.0%
Mustelid (small)	Mustelidae	4	0.0%		
Mustelid ind.	Mustelidae	1	0.0%		
Wolverine	*Gulo gulo*	1	0.0%	1	0.3%
Land mammal NISP		3409	36.8%	135	44.6%
Seal ind.	Phocidae	1592	17.2%		
Bearded seal	*Erignathus barbatus*	239	2.6%	12	4.0%
Ringed seal	*Phoca hispida*	217	2.3%	26	8.6%
Seal (small/medium)	Phocini	212	2.3%		
Harbour/Spotted seal	*Phoca* sp.	66	0.7%	10	3.3%
Ribbon seal	*Histriophoca fasciata*	15	0.2%	3	1.0%
Seal NISP		2341	25.2%	51	16.8%
Walrus	*Odobenus rosmarus*	72	0.8%	3	1.0%
Beluga	*Delphinapterus leucas*	48	0.5%	9	3.0%
Whale ind.	Cetacea	24	0.3%		
Whale (small)	Cetacea	9	0.1%	1	0.3%
Whale (large)	Cetacea	4	0.0%	1	0.3%
Porpoise	Phocoenidae	2	0.0%	1	0.3%
Marine mammal NISP		2500	27.0%	66	21.8%
Pacific salmon/trout	*Oncorhynchus* spp.	2118	22.8%		
Fish indeterminate	Osteichthyes	468	5.0%		
Fish NISP		2586	27.9%		
Duck ind.	Anatinae	186	2.0%	23	7.6%
Gull (large)	*Larus* sp.	102	1.1%	23	7.6%
Grouse/ptarmigan	Tetraonidae	55	0.6%	6	2.0%
Swan	*Cygnus* sp.	50	0.5%	12	4.0%
Murre	*Uria* sp.	37	0.4%	7	2.3%
Goose	*Anser sp./Branta sp./ Chen sp.*	33	0.4%	10	3.3%
Loon (small)	*Gavia stellata/Gavia pacifica*	28	0.3%	7	2.3%
Common raven	*Corvus corax*	26	0.3%	2	0.7%
Jaeger/Gull/Tern	Laridae	8	0.1%		
Puffin	*Fratercula* sp.	8	0.1%	3	1.0%
Loon (large)	*Gavia immer/Gavia adamsii*	7	0.1%	3	1.0%
Cormorant	*Phalacrocorax* sp.	6	0.1%	2	0.7%
Murre?	*cf. uria* sp.	5	0.1%		
Snowy owl	*Nyctea scandiaca*	4	0.0%	1	0.3%
Alcid ind.	Alcidae	3	0.0%		
Gull (medium)	*Larus* sp.	2	0.0%	1	0.3%
Puffin?	*cf. Fratercula* sp.	2	0.0%		
Sandhill crane	*Grus canadensis*	1	0.0%	1	0.3%
Short-eared owl	*Asio flammeus*	1	0.0%	1	0.3%
Bird ind.	Aves	82	0.9%		
Bird NISP		646	7.0%	102	33.7%
Molluscs	Bivalvia sp.	132	1.4%		
Total		9273	100%	303	100%

[a] Excl. antler.

being targeted for further processing activities (e.g. tool making) that took place on the house floors.

The technological sample studied (n = 1320) consisted mostly of antler, and comprised debitage (615 pieces), blanks (47) and preforms (20), along with 349 artefacts (including 134 weapons, and 157 tools). Among the faunal assemblage, 3321 specimens showed evidence for manufacture, with a predominance of caribou antler fragments involved (n = 2317). Bone (n = 594) and teeth (n = 357) fragments belonging to both terrestrial (caribou, dog, fox, wolf, mammoth) and marine species (walrus, beluga, sea birds) were identified. Although potentially available and in large quantities, with the exception of a few modified bearded seal ribs , seal bones do not appear to have been used in the bone technology at the site.

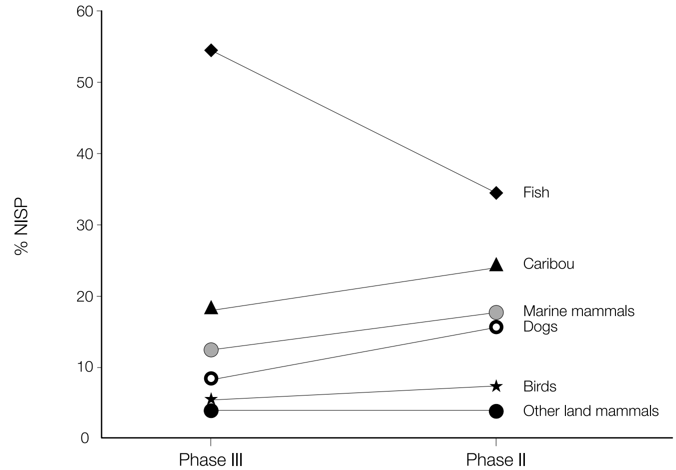

Fig. 4. Taxonomic spectrum in Phases II & III.

4.2. Dietary reconstruction at Nunalleq

To better reflect the true dietary contribution of each of the different animal resources at Nunalleq during the LIA, meat weight estimates were calculated (Needs-Howarth, 1995; Reitz and Wing, 2008) using average live weights derived from Alaska Department Fish & Game (www.adfg.Alaska.gov) and the published literature (Sale, 2006; MacDonald and Cook, 2009 and Fig. 5). Meat weight estimates were not calculated for fish or other non-mammalian species. In combination with the previously-published stable isotope data from human hair from Area C (directly inferring diet) and associated mixing models (suggesting the composition of dietary protein), a fuller picture of diet – including the contribution of fish – can be inferred (see Britton et al., 2018; McManus-Fry et al., 2018 and Fig. 6).

According to the stable isotope mixing model, salmon were amongst the most important vertebrate resources consumed at Nunalleq, providing up to 50% of the dietary protein (Britton et al., 2018 and Fig. 7). It is likely that salmon was not only consumed fresh but also as stored food (likely dried) based on the predominance of vertebrae in the assemblage (Hoffman et al., 2000). The storage of food is a critical component of prehistoric Arctic hunter-gatherer lifeways and the exploitation and curing of salmon in particular enables the production of storable surplus (Rowley-Conwy and Zvelebil, 1989). Of the mammalian species exploited, marine mammals, seals (28.9% estimated meat weight) and beluga (31.4%), were also important contributors to the diet based both on meat weights and the isotopic mixing model, where they ranked second behind salmon (Britton et al., 2018, Fig. 7). Marine mammals would also have provided significant amounts of fat and oil (Cachel, 2000; Kennett, 2005; Betts, 2016). Caribou (14.4% estimated meat weight) may not have been as important a source of protein in the diet as marine mammals and are secondary compared to salmon, seals or beluga, according to the isotope data. Caribou and large herbivores can also be an important source of fat to prehistoric hunter-gatherers in the form of body fat or marrow extracted from their bones (Speth and Spielmann, 1983). Though some spiral fracturing was observed on caribou long bones suggesting the extraction of marrow, smaller bones such as phalanges were not specifically fractured, most being recovered complete (Table 2), and there was no evidence of the preparation of 'bone broth' (Saint-Germain, 1997) suggesting that people at Nunalleq had access to sufficient amounts of fat from other sources, most likely marine mammals, and potentially did not suffer from severe dietary

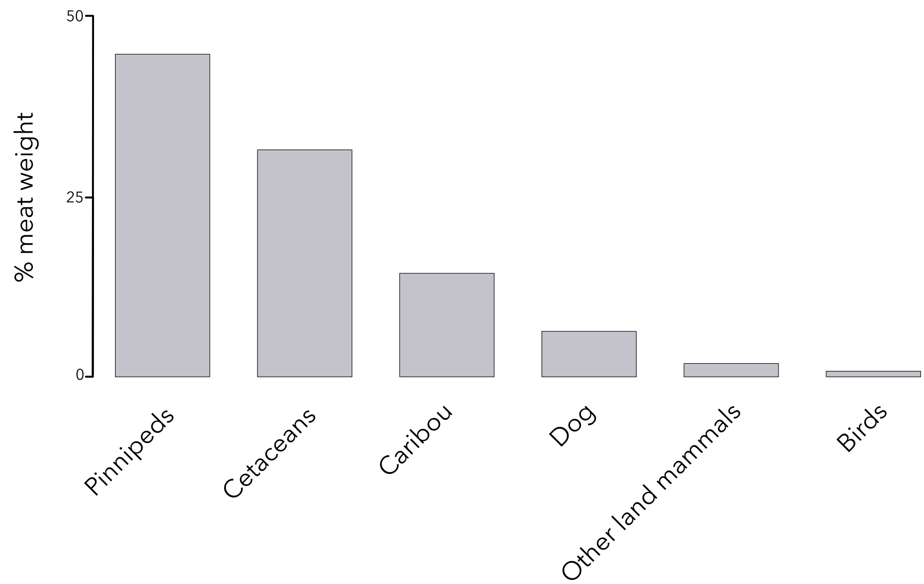

Fig. 5. Estimated dietary contribution of non-fish resources at Nunalleq based on meat weights (adapted from Masson-MacLean (2018)).

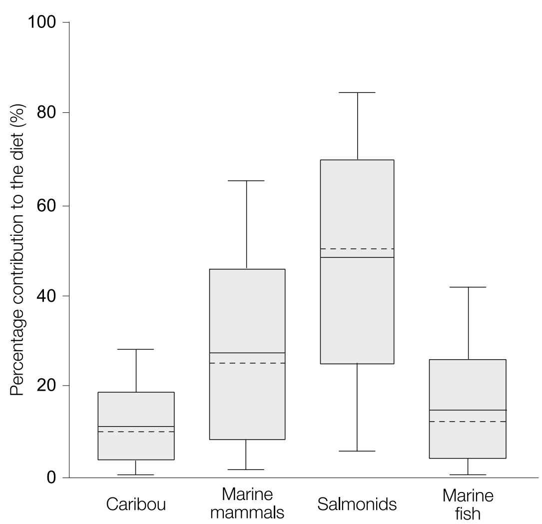

Fig. 6. Probability distribution of human diet composition, as estimated by FRUITS mixing model (adapted from McManus et al. 2018). Marine fish data taken from Byers et al. (2011).

Table 2
MNE of complete caribou phalanges.

Element		MNE	%MNE
Phalanx I	Complete	77	82.8
	Proximal	8	8.6
	Distal	8	8.6
	Total	93	100
Phalanx II	Complete	82	94.3
	Proximal	2	2.3
	Distal	3	3.4
	Total	87	100

stress (Outram, 2004). VanStone has already suggested that the abundance of natural resources in the Y.-K. Delta would have meant food shortages were likely to be less frequent and less severe than further north (VanStone, 1984b: 206).

The lack of marine fish other than salmon in the diet, based on the isotope mixing model, and the absence of their remains in the faunal record, infers that people exploited mainly the shallow coastal waters of the Kuskokwim Bay and fishing further out in the ocean was either not necessary or not viable. The latter may be particularly relevant during the harshest decades of the Little Ice Age and periods of increased

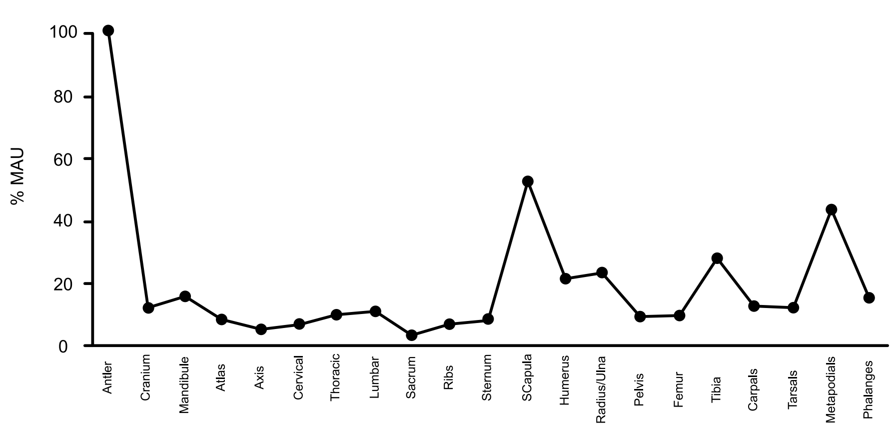

Fig. 7. Caribou skeletal representation at Nunalleq based on Minimal Animal Unit (MAU).

storminess (Mason and Gerlach, 1995; West, 2009b). While birds do not figure in the mixing model and their contribution to the overall yearly diet may have been minimal, it is likely that their availability and consumption at specific times of the year (including eggs) might have been crucial (Moss and Bowers, 2007; Miisaq/Andrew, 2008).

While some changes in the composition of the faunal assemblage were noted between the different phases of the site, actual dietary changes during the occupation of the site are more difficult to infer. While there is better representation of both caribou and marine mammals in the later phase (II), along with a decrease in fish remains, the rank order of resources does not change. Furthermore, Friesen and Betts (2002) have demonstrated intra-site variations in the composition of Thule-era faunal assemblages depending on on-site provenience. Future work should include integrating data from earlier phases recently excavated at the site, as well as further diachronic isotope analysis on human hair. It is nevertheless interesting that this apparent decline in a major subsistence resource (salmon) occurred during the Little Ice Age, a well-documented period of harsher conditions across the globe (Parker, 2013) that could also have had a negative effect on salmon populations (Finney et al. 2000).

4.3. The importance of caribou bone and antler in the manufacturing of objects and hunting implements

Except for beluga (represented primarily by mandibular fragments and isolated teeth) other major taxa such as seals and caribou were represented by most body parts, suggesting they may have been hunted relatively close to the site (Masson-MacLean, 2018). Of interest for this study was the over-representation (other than of antler) of certain caribou elements such as scapulae and metapodials (Fig. 8), which also showed the highest frequencies of working (Table 3). Furthermore, the assessment of worked bone at the site highlighted the importance of caribou elements in the bone-working industry in general (58% of total worked bone in the assemblage). This differed significantly to seals whose main function appears to have been primarily dietary, though, in the ethnographic record, their hides are known to be valuable (VanStone, 1984a; Fienup-Riordan, 2007). Except for very few modified ribs of the large bearded seal, possibly used as root picks, and small wedges, seal bones were generally not used as raw material for manufacturing tool or objects.

The amount of worked bone, however, is dwarfed by the vast amount of worked antler pieces recovered from the assemblage. Both cut antler from freshly slaughtered caribou (MNE = 37; MNI = 18) and naturally shed antler (MNE = 87; MNI = 43) were present. Shed antler predominates (twice as frequent as cut antler), indicating the need to supplement the amount of antler acquired from hunted caribou by collecting additional antler from the tundra. The distribution of cut antler is evenly distributed across the various size categories (i.e. small to large sets), contrasting with that of the naturally shed antler, which is dominated by medium to large antler (Fig. 8). It appears, therefore, that when collecting naturally shed antler from the surrounding environment, there was a preference to select larger specimens.

These data highlight the importance of antler as a raw material. This is also confirmed by the study of the antler debitage, which revealed the multiple uses of antler for manufacturing various objects and implements for subsistence and warfare, as well as for domestic and social purposes (Fig. 9). Of the 2867 pieces of worked animal remains for which the material could be identified, just over 80% (2317) was antler. Thus, the technology used for the hunting of key animal resources such as seals (harpoons), caribou (arrowheads) and birds/fish (prongs) were predominantly made from antler (Table 4) emphasizing the importance of antler in the Y.-K. Delta during pre-contact times.

5. Discussion: pre-contact adaptations to the Little Ice Age in the Y.-K. Delta

5.1. Site location: a tripartite resource-base

Based on the faunal and technological data explored above, combined with stable isotope data from the site, the inhabitants of Nunalleq were engaged in a tripartite resource-based economy focused primarily on the exploitation of salmon, marine mammals (mainly seals) and caribou. These animal resources provided the bulk of the diet, as well as being a critical source of raw materials for making clothes, tools and hunting equipment. Caribou antler was a vital raw material resource in non-dietary aspects of subsistence. This pattern has also been observed for other archaeological coastal groups in Southwest Alaska whose economy was defined by a lack of larger sea mammals and a focus on salmon, seals and caribou (Bockstoce, 1979, 89). These resources most likely reflect what was available locally, as late prehistoric and historic Arctic hunter-gatherers generally tended to exploit what was available within a relatively close radius from a winter settlement (Betts, 2008: 140–144). People at Nunalleq had nearby access to two highly productive salmon rivers in the Kanektok and Arolik. The location of the site on the shores of the Kuskokwim Bay would also have provided easy access to marine mammals and non-salmonid fish, although the latter do not seem to have played a major role in diet at the site.

Caribou appear to have been hunted sufficiently close to the site for complete caribou carcasses to have been brought back to the settlement. There is ethnographic evidence of large migrating caribou herds along the Bering Sea coast in the 19th century (Burch Jr. 2012). This was also likely to have been the case during the pre-contact period based on recent strontium isotope data obtained from caribou teeth from Nunalleq, which indicate caribou hunted at the site were seasonally migratory and possibly present on the coast during winter (Gigleux et al., 2019). The lack of squirrel remains is in contrast to

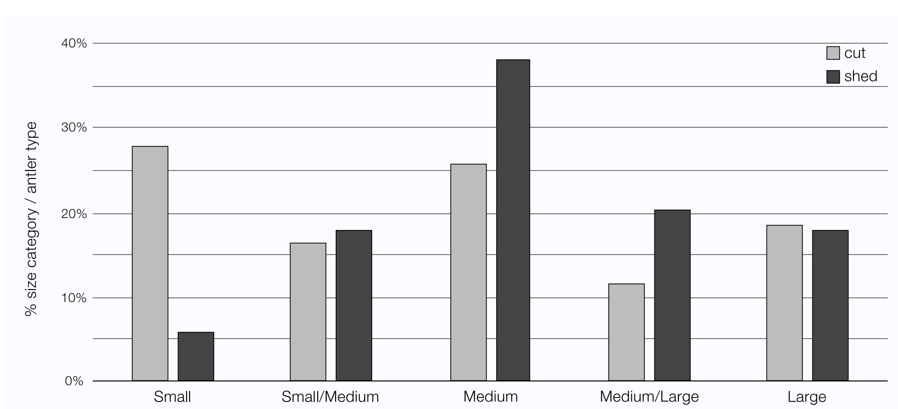

Fig. 8. Antler acquisition at Nunalleq.

Table 3
Worked bone at Nunalleq per taxon (Sample studied = 238 out of 594).

	Taxon	Cranium/ Teeth	Rib	Scapula	Humerus	Radius/Ulna	Baculum	Femur	Tibia/ Fibula	Metapodials	Carpals/ Tarsals	Other	wNISP	%wNISP
Beaver	*Castor canadensis*	1											1	0.4%
Beluga	*Delphinapterus leucas*	5											5	2.1%
Domestic dog	*Canis familiaris*	3				1							4	1.7%
Caribou	*Rangifer tarandus*	4		37		1		1		65	5		113	47.5%
Wolf	*Canis lupus*	2						2					4	1.7%
American mink	*Neovison vison*	1											1	0.4%
Porcupine	*Erethizon dorsatum*	17											17	7.1%
Bear	*Ursus sp.*							1	1				2	0.8%
Fox	*Vulpes sp.*	13											13	5.5%
Walrus	*Odobenus rosmarus*	3	2	1			1			5			12	5.0%
Gull	*Larus sp.*				8	1							9	3.8%
Goose	*Anserini sp.*				7								7	2.9%
Loon	*Gavidae sp.*				15							1	16	6.7%
Puffin/Murre	*Fratercula sp.*											1	1	0.4%
Swan	*Cygnus sp.*				26							2	28	11.8%
Common raven	*Corvus corax*				3								3	1.3%
Cormorant	Phalacrocoracidae											1	1	0.4%
Murrre	*Uria sp.*											1	1	0.4%
	Total	49	2	38	59	3	1	4	1	70	5	6	238	100.0%

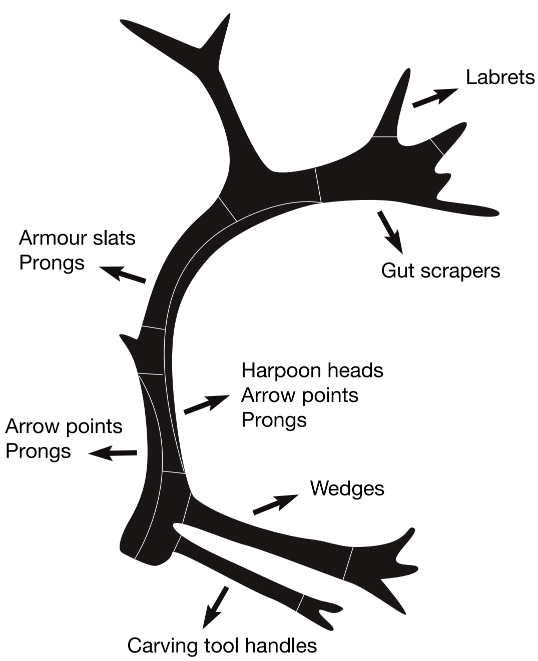

Fig. 9. The debitage reduction process and use of antler at Nunalleq.

Table 4
Subsistence equipment at Nunalleq.

Artefact type	Antler	Bone	Ivory	Lithic	Total
Arrow point	145	3	1		149
Bola		1	1		2
Bow	2	1			3
Fish hook	1	3			4
Fish lure	5	4	10	5	24
Harpoon head	87	12	1		100
Lance				8	8
Prong	224	9	37		270
Sinker	3	13			16
Socket piece for harpoon	16	28	17		61
Total	490	75	68	21	654

ethnographic accounts of the importance of this species in the recent historic period (a likely consequence of the fur trade) and suggests limited excursions to mountainous areas. The low representation of taxa occupying tundra and riverine habitats also emphasises the coastal focus of subsistence at Nunalleq. It is, therefore, likely that the location of the Nunalleq site was influenced by access to multiple high-ranking animal resources that could provide critical raw materials and food (including the necessary amounts of fat - mainly acquired from marine mammals) needed to survive in Arctic environments (Speth and Spielmann, 1983; Cachel, 2000), not least during the Little Ice Age. However, access to non-animal resources such as driftwood may also have been a factor in site location decisions, given its economic and cultural importance amongst Yup'ik coastal communities (Wheeler and Alix, 2004). The location of the Nunalleq site on a resource hotspot mirrors settlement patterns observed among Mackenzie Delta Inuit in Arctic Canada (Betts, 2008) and in pre-contact Southwest Alaskan contexts (Crowell et al., 2011) and can be considered a key adaptive strategy of Arctic foragers, especially during periods of climatic instability and inclemency.

5.2. A flexible subsistence strategy and coping mechanisms

The location of Nunalleq would have provided its inhabitants with the means to practice a flexible subsistence strategy with access to several key resources, as well as potentially important secondary resources such as migratory birds. This exploitative pattern would have provided the ability to cope with changes in environmental conditions affecting species availability and distribution with environmental or climatic anomalies unlikely to have had the same effect on all species equally. Resource flexibility and storage are considered a risk-minimising strategy, providing a buffer against potential pitfalls in resource availability (Hayden, 1981; Rowley-Conwy and Zvelebil, 1989). The storage of food, and salmon in particular - a relatively resilient and predictable resource (Campbell and Butler, 2010) - and a tripartite subsistence strategy, most likely provided pre-contact populations in the Y.-K. Delta with the necessary tools to cope with rapid fluctuations in environmental conditions characteristic of Arctic habitats (Rowley-Conwy, 1999, 353), which may have potentially been exacerbated by the Little Ice Age.

Hunter-gatherers tend to manage risk by diversifying their resource base, allowing them to substitute a failing resource by another as they possess the knowledge and skills to do so (Kelly, 2013, 69). This strategy appears to have been mastered by Thule-era foragers across the

Arctic (Betts, 2008, 2016) - including at Nunalleq whose inhabitants possessed the necessary fishing and hunting technology to acquire multiple key resources and, therefore, take advantage of their environment. Along with settlement patterns and a flexible subsistence strategy, technology is considered a major component of prehistoric hunter-gatherer resilience (Solich and Bradtmoller, 2017). The material cultural assemblage at Nunalleq, including bone technology, highlights a well-adapted, sophisticated technology. Furthermore, the presence of loose and fixed harpoon foreshafts as well as barbed and toggling harpoons suggests the ability to hunt seals from kayaks in open water, from the ice edge and at breathing holes in the ice (Morrison 1983), thus taking advantage of the different ocean and sea-ice conditions that may have been both more extensive and more variable during the Little Ice Age than today. The widespread use of caribou antler for manufacturing fishing, sea mammal and bird hunting implements – including evidence for collecting significant amounts of shed antler from the tundra – not only highlights the importance of this material but also its availability. The lack of worked seal bones may indicate that people at Nunalleq had sufficient access to more attractive sources of raw material in the form of antler or walrus ivory. Antler, in particular, is tougher and has superior mechanical properties than bone (MacGregor and Currey, 1983). Besides, seal bones are morphologically difficult to work and it also seems unlikely that taboos prevented their use for making tools as at least some bearded seal ribs were modified. Caribou are indeed often an integral part of Arctic prehistoric economies, not only as a source of food (meat, fat), but also (and often more so) as a source of raw materials for clothing and the manufacture of objects and tools (Burch, 1972; Binford, 1978; Gerlach, 1989; Betts, 2016, 92). Winter clothing is a vital component of Arctic lifeways and the importance of caribou skin to Arctic societies results mainly from its high insulating qualities with ethnographic accounts suggesting that the value of caribou as a source of skin was equal, if not higher, than its value as a source of food (Stenton 1991: 18). Though the material has yet to be fully analysed, evidence of skin working and sewing has also been recovered at Nunalleq - including leather garments and fragments with stitches, made of caribou and other animals skin (pers. comm. J. Masson-MacLean), awls, skin scrapers and needles. Furthermore, it has been argued in Arctic environments that effective coastal adaptations were possible by relying on terrestrial resources (Stenton 1991: 17, Hodgetts, 2000). It can, therefore, be suggested that caribou, and caribou antler and hide in particular, as valuable raw materials, may have been central for supporting a maritime-based economy along the Kuskokwim Bay coast, especially considering that the shallow waters of the bay restricts access to large cetaceans and walrus.

The technology and knowledge to rely on multiple key resources, but also the ability to exploit a wide range of resources such as birds and a variety of land mammals at Nunalleq, further increases the capacity of hunter-gatherers to cope with fluctuations in primary animal resource availability (Kelly, 2013: 69). For example, in the Canadian Arctic pre-Dorset people increased their intake of secondary resources such as foxes and Arctic hare as a response to decreasing availability of high benefit seals and large herbivores (Darwent, 2004). In the Y.-K. Delta, according to the Yup'ik ethnographic record, migratory birds were a critical resource at specific times of the year such as the early spring, when winter stored supplies were low and people were waiting for the arrival of seals (Miisaq/Andrew, 2008) and this may also have been the case prior to contact. Another fall-back resource available year-round for Thule-era people across the Arctic would also have been dogs. The dog remains at Nunalleq, including the high ratio of juveniles (McManus-Fry, 2015; Masson-MacLean, 2018), and associated butchery, is indicative of their at least occasional consumption, most likely during episodes of food scarcity and hardship, as observed in other Arctic prehistoric and historic contexts (Park, 1987). Indeed, dogs would have formed a readily available source of protein that could be acquired with minimum energy expenditure acting as a supplementary buffer when encountering difficulties in food procurement. Given the additional pressure dogs placed upon other subsistence-acquired resources, population control through culling would also have been an important aspect of animal and resource management during periods of hardship.

5.3. *A successful adaptation during the Little Ice Age?*

The apparent decline in salmon exploitation during the latest occupation phase of the site could perhaps be related to episodic extreme conditions during the Little Ice Age affecting salmon populations and spawning (Brannon et al., 2004). Although further diachronic isotope analyses at the site are required to infer a more detailed picture of diet through time, the inhabitants of Nunalleq appear to have compensated for the decline in salmon by relying more on other major resources such as seals and caribou but also by increasing their consumption of dogs. However, the lack of fractured caribou phalanges may provide evidence that people at Nunalleq did not experience extreme dietary stress nor had the necessity to exploit animal fat from bones with low marrow extraction efficiency (Outram, 2004: 77).

The coastal location of the site on a resource hotspot, a flexible tripartite subsistence strategy and the knowledge and technology to exploit a variety of species, suggests that the coping mechanisms were efficient with dealing with potential severe conditions and localised disruptions to resource availability that are perhaps more likely to have occurred at the height of the LIA during the 17th century (Parker, 2013). Unlike some parts of Alaska, or the Arctic, where people relocated or migrated as a response mechanism to harsher environmental conditions during the LIA (Mason and Gerlach, 1995; Sørensen, 2010), people at Nunalleq seemed to have benefited from good access to resources from a 'central place,' enabling them to occupy the site for at a least a century (Ledger et al., 2018). Even today, people in Quinhagak – the modern settlement close to the archaeological site – consider their village to be located on a better "spot" for accessing multiple animal resources than other villages in the area (Warren Jones pers. comm.). It may be that the location of the site on the coast, with ready access also to inland and riverine resources, may explain the warfare-related destruction of Nunalleq as competing groups vied for access to this resource-rich prime settlement location (Kurtz, 1985; Fienup-Riordan and Rearden, 2016).

6. Conclusions

People at Nunalleq practiced a flexible tripartite subsistence strategy focused on the acquisition of salmon, marine mammals (specifically seals) and caribou, with a range of secondary resources such as migratory waterfowl also exploited. The knowledge and technology necessary to exploit a variety of resources, the ability to switch the focus from one key resource to another, and the possibility to store food surplus provided people with the necessary coping and buffering mechanisms to avoid dietary stress effectively during one of the most severe episodes of the Little Ice Age. Furthermore, at this coastal site, the technological record highlights that one of the most important aspects of successful coastal adaptation in SW Alaska during this period was the exploitation of caribou as a source of raw material for manufacturing associated acquisition technologies. The decision to locate at the site may well have been dictated by the possibility to simultaneously exploit multiple key animal resources, accessing the coast and the seasonally migrating salmon and herds of caribou. However, access to other resources, such as driftwood, may also have played a role in site location, and future investigations of pre-contact Yup'ik settlement patterns should include all resource types.

The apparent advantageous location of Nunalleq may also have been a reason for its demise, as the Little Ice Age could have affected the distribution and abundance of certain key species, possibly increasing stress and competition between groups over key resources. It is only by further developing interdisciplinary approaches and combining multiple lines of evidence such as biological remains, technology and isotopes, as well as ecological and climatic modelling, that human adaptations and the effects of the Little Ice Age on both people and resources in SW Alaska and beyond will be more fully understood.

Acknowledgements

This work was funded by an AHRC-LabEx award (AH/N504543/1) to KB, RK, KD and IS and an Arts and Humanities Research Council (AH/K006029/1) grant awarded to RK, KB and Charlotta Hillerdal (Aberdeen). The onsite collection of samples was carried out by staff and students from the University of Aberdeen, volunteer excavators and the residents of Quinhagak. We had logistical and planning support for fieldwork by the Qanirtuuq Incorporated, Quinhagak, Alaska, and the people of Quinhagak, who we also thank for sampling permissions. Special thanks to Warren Jones, John Smith and Qanirtuuq Incorporated (especially Michael Smith and Lynn Church), and to all project team members, in Aberdeen and at other institutions. The first author particularly wishes to thank Christine Lefèvre (Muséum national d'Histoire naturelle, Paris), Aren Gunderson and Link Olson (University of Alaska Museum of the North, Fairbanks) and Zena Timmons and Jerry Herman (National Museum of Scotland) for facilitating access to their respective institutions reference collections and taking the time to share their knowledge on the zoology of bird and marine mammals. We extend particular thanks to Véronique Forbes and Paul Ledger for their valuable comments on the final draft of the paper. The authors also wish to sincerely thank the anonymous reviewer for very constructive comments. Finally, thank you to Peter Jordan (University of Groningen) for inviting us to contribute to this special issue and for his patience.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2019.05.003.

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