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Diversity in Labrador Inuit sled dog diets: Insights from $\delta^{13}C$ and $\delta^{15}N$ analysis of dog bone and dentine collagen

Alison J.T. Harris[a,b,c,*], Deirdre A. Elliott[c], Eric J. Guiry[d,e,f], Matthew Von Tersch[b], Lisa Rankin[c], Peter Whitridge[c], Michelle Alexander[b], Gunilla Eriksson[a], Vaughan Grimes[c,g]

[a] Department of Archaeology and Classical Studies, Stockholm University, Stockholm 10691, Sweden
[b] Department of Archaeology, University of York, York, United Kingdom
[c] Department of Archaeology, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, Canada
[d] Department of Anthropology, Trent University, Peterborough, Ontario, Canada
[e] Department of Anthropology, University of British Columbia, Vancouver, British Columbia, Canada
[f] School of Archaeology and Ancient History, University of Leicester, Leicester, United Kingdom
[g] Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, Canada

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ABSTRACT

Sled dogs were an integral part of Labrador Inuit life from the initial expansion and settlement of northeastern Canada to the present day. Tasked with pulling sleds and assisting people with other subsistence activities in the winter, dogs required regular provisioning with protein and fat. In this paper, we conduct stable carbon and nitrogen isotope ratio analysis of the skeletal remains of dogs (n = 35) and wild fauna (n = 68) from sites located on the north and south coasts of Labrador to characterize dog provisioning between the 15th to early 19th centuries. In addition, we analyse bone (n = 20) and dentine (n = 4) collagen from dogs from Double Mer Point, a communal house site in Hamilton Inlet to investigate how dog diets intersected with Inuit subsistence and trade activities at a local level. We find that dog diets were largely composed of marine mammal protein, but that dogs on the north coast consumed more caribou and fish relative to dogs from the central and south coast sites. The diets of dogs from Double Mer Point were the most heterogenous of any site, suggesting long-distance movement of people and/or animals along the coast.

1. Introduction

Biomolecular approaches to the zooarchaeology of dogs, including stable isotope analysis and ancient DNA (aDNA), can speak to canine population histories and human-canid relationships over the course of our shared history. In Inuit cultures, dogs provided traction, hunting assistance, food, fur, protection and companionship, and in exchange, required food. Historically, Inuit and related Yup'ik cultures inhabited a range of environments and engaged in regionally and culturally distinct subsistence activities with implications for dog provisioning (Britton et al., 2018; Betts, 2005; Savelle, 2002). For example, Alaskan communities of the pre-contact and modern eras provisioned dogs with salmon, a resource that could be acquired in bulk and dried (Loftus et al., 2014; McManus-Fry et al., 2018). Human-canine relationships and the position of dogs among communities of the western and central Arctic have been further examined using osteometric, archaeological, ethnographic and genetic data (Brown et al., 2013; Coltrain et al., 2004; Davydov and Klokov, 2018; Hill, 2018; Losey et al., 2018; Morrison, 1984; Park, 1987; Pitulko and Kasparov, 2017; Strecker, 2018) but to date similar research in the Eastern Arctic and Subarctic is limited in scope (Ameen et al., 2019; Woollett, 2003). In Labrador, Canada, food resources varied with the season and location; Inuit communities moved seasonally to access patchy resources and to engage in long distance trade networks. Dog diets may reflect the geographic and seasonal distribution of prey resources, and the need to provision dogs with foods that could be stored and transported, or easily acquired while on the move.

To understand the reciprocal interactions of human subsistence activities, dog provisioning, and labour, we conducted the first carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratio study of Labrador Inuit dogs from five archaeological sites spanning the Labrador coast. We contextualized the data against the isotopic composition of local wild fauna to identify possible dietary protein sources. We paired a regional survey of dog diet with an intra-site analysis of dog teeth and bones from the

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* Corresponding author.
E-mail address: alison@palaeome.org (A.J.T. Harris).

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site of Double Mer Point and consider these data with respect to the local environment, the seasonal subsistence base, and the role of Double Mer Point in Inuit coastal trade networks.

1.1. Archaeological context

The ancestors of Labrador Inuit left the western North American Arctic and rapidly explored and settled the Eastern Arctic (including the Canadian Arctic Archipelago and Greenland) during the first half of the 13th century (Friesen, 2019; McGhee, 2009). This territorial expansion was facilitated by an economic dependence on arctic marine mammals, and by Inuit mastery of long-distance travel over snow and ice using dog traction technology, and over water using skin-covered boats (*kajat* and *umiat*). The movement of Inuit into the Labrador peninsula has been dated to ∼1450 at sites north of Nain (Kaplan, 1983; Whitridge, 2012, 2016), and between the late 16th and 17th centuries Inuit had expanded their seasonal settlement pattern as far south as the Quebec Lower North Shore (Fitzhugh, 2015, 2016; Rankin, 2015; Stopp, 2002). During this early period of exploration, Inuit constructed small, sometimes multi-lobed, semi-subterranean houses in the outer coastal areas of Labrador, and hunted large whales, multiple species of seal and fish, and terrestrial animals (Kaplan and Woollett, 2016). Inuit came into contact with traces of Basque whalers and French fishers who had established shore stations along the southern coast of Labrador for the intensive harvesting of Atlantic cod (*Gadus morhua*) and bowhead whales (*Balaena mysticetus*) (Barkham-Huxley, 1984; McLeod et al., 2008; Pope, 2015; Rastogi et al., 2004; Stopp, 2002). Through informal trade and seasonal looting of abandoned whaling and fishing stations, Inuit incorporated European-manufactured materials (modified iron nails, roofing tiles, hardwood) into their toolkit (Jordan, 1978; Rankin and Crompton, 2016a). Inuit developed a long-distance trade network, powered by influential middlemen traders, to move European goods and Inuit-harvested raw materials (baleen, seal and whale oil) up and down the coast (Taylor and Taylor, 1977). As European harvesting depleted the stocks of baleen whales and walrus, seal increasingly became the focus of Inuit subsistence (Fitzhugh, 2016). A change in architectural style, from single-family dwellings to large semi-subterranean dwellings with multiple sleeping platforms and lamp stands, occurred by the mid-17th century and was widely adopted during the 18th century (Rankin, 2014). The onset of this Communal House Phase may have been stimulated by cooperative seal hunting, or have been an effective means to trade European goods, organize labour, and boost social status (Fay, 2015; Rankin and Crompton, 2016b; Jordan, 1978; Kaplan and Woollett, 2000; Woollett, 2003). Hamilton Inlet, the geographic focus of our study, was a prime locus for trade in the latter half of the 18th century. Inuit in Hamilton Inlet could enter into trade with Quebec-based and English merchants, who had several posts through the 18th century along the shores of Lake Melville and Hamilton Inlet, while maintaining access to the abundant food resources available in The Narrows (Bohms, 2018). Hamilton Inlet was also used by Inuit overwintering on trading journeys between northern and southern Labrador (Kaplan, 1983; Taylor, 1974). Following the 1763 Treaty of Paris, Labrador was ceded to the British, and French posts and stations were slowly abandoned (Rankin et al., 2012). Though British merchants were not at first permitted to settle, the Moravian Church was granted 100 000 acres of land in Northern Labrador, and established mission stations at Nain (1771), Okak (1776) and Hopedale (1782) to Christianize the Inuit and regulate Inuit-European interactions. More stations were opened to the north and south beginning in 1830, but these early stations were particularly important in the way they disrupted the previously-established north–south Inuit trade routes by providing an alternative, northern entry point for many (but not all) European-manufactured goods (Rollmann, 2011; Taylor, 1976).

1.2. Dogs and Inuit culture

Human-dog interactions in Arctic communities have historically represented a reciprocal relationship wherein dogs exchanged labour for food, and humans laboured to feed dogs. In Arctic contexts where food resources can be acquired in bulk, dogs are commonly known for pulling sleds and assisting with subsistence activities (Davydov and Klokov, 2018). In some communities it was acceptable to consume dog meat (Park, 1987), while in others this practice was taboo, or reserved for times of economic hardship (Rasmussen, 1929). Dogs provided durable, moisture-resistant fur for lining mittens, trimming the hoods of parkas, and forming the outer portion of sealskin boots (Issenman, 2011). Additionally, dogs were tightly integrated into Inuit cosmology and could hold social roles within their communities (Laugrand and Oosten, 2002).

The earliest evidence for circumpolar dog sledding, dating to c. 8000 BP, was found on Zhokhov Island in the Siberian High Arctic (Pitulko and Kasparov, 1996, 2017). Whitridge (2018) suggests that the complete dog traction kit, including the sled (*komatik*) and its components, trace buckles, lines, and whips arose in the western Canadian Arctic, effectively enabling the rapid Inuit expansion eastwards. At regional scales, dog sledding served to connect communities (Sheppard, 2004), leading Birket-Smith (1945) to categorize dog traction as a mode of communication in the Arctic. Dogs were critical players in the seasonal mobility practices of Labrador Inuit. Pulling sleds from December through June, dogs moved entire households between autumn–winter and spring habitation sites along the coast and carried caribou carcasses from hunting camps in the interior (Woollett, 2003). The possession of a dog team allowed greater participation in pre-19th century Inuit trade networks, and increased the status of middlemen traders (Fay, 2015). By the late 18th century, some Inuit families on the north coast were in possession of up to 28 dogs and were capable of moving a large amount of goods across the landscape (Taylor, 1974). Humans also relied on dogs to navigate the landscape and scent prey (Whitridge, 2018). When traveling between communities during bad weather, dogs could be relied upon to scent human habitation sites (Rasmussen, 1929). The use of dog teams for subsistence and trade activities continued until the adoption of snowmobiles in the 20th century (Smith, 1972), and is today a popular winter sport (Labrador Winter Games Association, 2019). After the introduction of snowmobiles to northern communities, former dog team owners observed a change in their own behaviours to compensate for the loss of the sensory capabilities of dogs,

> “By using a skidoo as your machine for transportation, you tend to sharpen your own senses: smell, eyes, your sense of direction in the dark or in a storm, and your prediction of the weather. These things were not really sharp before, because you had dogs. If you were going to go somewhere, they would probably know which way to go anyway, because all the things you knew went to the leader, and he recorded where he had been before.” (Brody, 1977: 322-323).

As one of the outcomes of domestication was the disruption of natural hunting behaviours (Boitani and Cuicci, 1995; Zeder, 2012), dogs are the only domesticate that, historically, needed to be provisioned with the flesh of other animals. Domestication carries the obligation to feed (Losey et al., 2018) and dog team owners could incur significant financial and labour costs while doing so (Krupnik, 1993; Rasmussen, 1929). Sled dogs require diets rich in fat to meet the energy requirements of pulling sleds and to maintain body temperature (Lupo, 2019; McManus-Fry et al., 2018). Rasmussen (1929) observed that sled dogs fed caribou quickly grew lethargic while those fed walrus meat and blubber could work for longer periods of time, potentially biasing dog diets toward marine sources of protein.

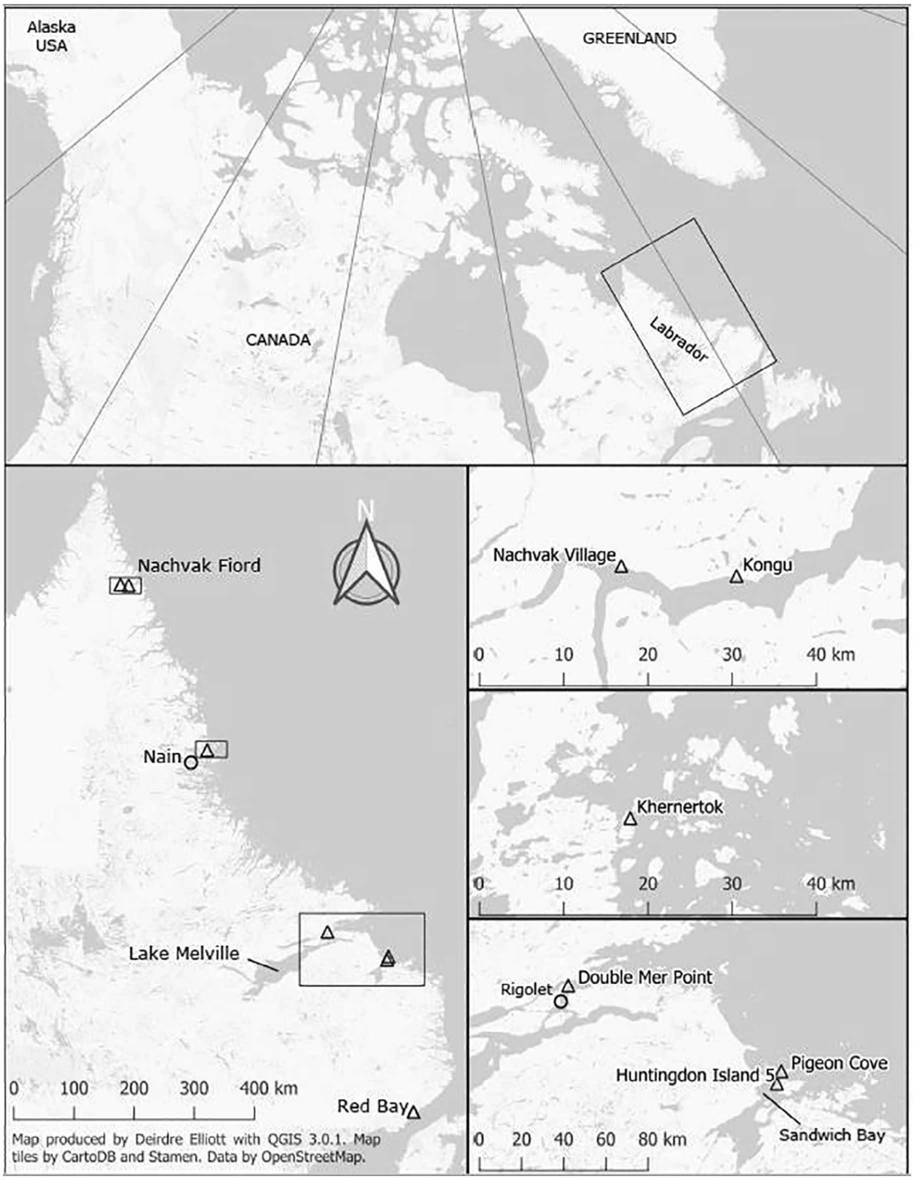

Fig. 1. Map of study region with Inuit and Basque sample sites.

1.3. Double Mer Point and Hamilton Inlet, Labrador

Hamilton Inlet is located on the central Labrador coast. It extends from the Labrador Sea inland to Lake Melville and encompasses the marine environments of Groswater Bay, Back Bay, Double Mer, and the Narrows. Double Mer Point (GbBo-02) is located near the town of Rigolet (Fig. 1) and is the site of three contiguous Inuit winter houses that, based on artefact typologies, were occupied in the latter half of the 18th century and abandoned by approximately 1840 (Bohms, 2018; Jordan, 1974, 1977; Pouliot, 2020; Rankin, 2014). Winters are long with abundant precipitation and land-fast ice occurs between late December and May/June (Ames, 1977; Fitzhugh, 1972). Swift tidal currents flow around Double Mer Point and provide areas of open water that persist during the winter, except under the coldest conditions (Fitzhugh, 1972). Ringed seals (*Pusa hispida*), a source of meat and hides, were present year-round and could be hunted through breathing holes on fast ice, caught in polynyas during the winter, or when basking in the spring (Woollett, 1999). Harbour seals (*Phoca vitulina*), prized for their hides (Elliott, 2017), were more numerous in the summer, but could be hunted during the winter around polynyas and at the ice floe edge (Woollett, 1999). Harp seals (*Pagophilus groenlandicus*) were sometimes taken in large numbers as they foraged in Hamilton Inlet on their southward autumn migration (Elliott, 2017; Woollett, 1999). Grey (*Halichoerus grypus*) and bearded seals (*Erignathus barbatus*) were less frequent visitors, and the three small species of seal (Harbour, Harp, and Ringed) compose the majority of identified species in faunal assemblages from Hamilton Inlet (Bohms, 2018; Brandy, 2013; Elliott, 2017; Jankunis, 2019; Woollett, 1999). Other marine sources of dog food at Double Mer Point include capelin (*Mallotus villosus*), which could be collected *en masse* during summer spawning episodes, Arctic char (*Salvelinus alpinus*), Atlantic salmon (*Salmo salar*), and numerous species of migratory and non-migratory waterfowl and their eggs (Ames, 1977; Elliott, 2017; Fitzhugh, 1972).

Caribou (*Rangifer tarandus*) and other terrestrial mammals were of secondary importance to the residents of Hamilton Inlet. Four caribou herds, including both barren ground and woodland types, were present in the spruce forests and tundra to the south and north of Hamilton Inlet (Fitzhugh, 1972). Caribou contributed antler and bone for tool making, and their hides were important for warm winter clothing, while foxes and other fur-bearers were trapped for furs, an activity that increased among the Inuit of Double Mer Point and Hamilton Inlet over the 19th century in response to European demand (Ames, 1977). Numerous varieties of berries grow on the exposed hillsides and islands near the site and include cloudberries (bakeapples), crowberries (blackberries), partridgeberries (redberries), and blueberries (Mitchell, 2014).

1.4. Stable isotope analysis and dog diets

Stable carbon and nitrogen isotope analysis of bone collagen is routinely employed to analyse the diets of archaeological humans and fauna as collagen reflects a long-term average of consumed dietary protein (Fernandes et al., 2012; Hedges et al., 2007). The turnover of dog bone collagen varies by dog skeletal element: approximately 30% of alveolar bone is replaced each year, while femoral bone collagen has a much slower turnover rate of 6% per year (Huja et al., 2006). Comparisons of different proteins, such as keratin and collagen, (e.g. McManus-Fry et al., 2018), or of different skeletal elements can be used to effectively study dog diets over multiple time scales. The permanent dentition of a dog develops during the first six to eight months of life, and by comparing the δ^{13}C and δ^{15}N values of dentine and bone collagen, it is possible to identify dietary continuity or change at different periods in a dog's life.

In Arctic and Subarctic contexts, δ^{13}C values distinguish marine and terrestrial sources of protein as mid- and high-latitude marine species have higher δ^{13}C values than terrestrial species (Schoeninger and DeNiro, 1984). Measured δ^{13}C values from archaeological seal, fish, and seabirds from Eastern Arctic and Subarctic contexts range from −10‰ to −16‰, while the δ^{13}C values of caribou and other terrestrial game are, on average, lower than −18‰ (Guiry et al., 2012; Guiry and Grimes, 2013; Harris et al., 2019; Nelson et al., 2012). Bone collagen δ^{13}C values are offset from diet by approximately +5‰ but this number can vary between +2‰ and +10‰ with dietary regime (Ambrose and Norr, 1993). This source of uncertainty can be circumvented by a direct comparison of consumer and prey bone collagen δ^{13}C values as these are offset by approximately +1‰ (Bocherens and Drucker, 2003). Trophic interactions can be estimated by comparing the δ^{15}N of different taxa as consumers have higher (+3 to +5‰) δ^{15}N values than their prey (Bocherens and Drucker, 2003; Hedges and Reynard, 2007; Shoeninger and DeNiro, 1984; van Klinken et al., 2002). The δ^{15}N value of collagen can also be affected by an animal's nitrogen balance. Episodes of physiological stress (illness, injury, malnutrition) can prompt skeletal muscle to release amino acids back into the amino acid pool for tissue synthesis (Mekota et al., 2006). This increases collagen δ^{15}N values and may also decrease δ^{13}C values if body lipids are increasingly used for amino acid synthesis (Neuberger et al., 2013).

Marine foodwebs are typically longer than terrestrial foodwebs, and marine carnivores, such as polar bears, may have δ^{15}N values greater than +18‰, while terrestrial herbivores and carnivores have δ^{15}N values below +12‰ (Bocherens et al., 2016; Cherry et al., 2011, Nelson et al., 2012). Freshwater species were of less economic importance in coastal Labrador, but anadromous fish species, such as Arctic char and Atlantic salmon were seasonally accessible from coastal locations (Ames, 1977; Brice-Bennett, 1977). The δ^{15}N and δ^{13}C values of anadromous fish species vary with age; smolts yet to winter in the ocean have lower δ^{13}C values than adults returning from the marine environment (Dixon et al., 2012).

Stable isotope investigations of domestic dog diets in Alaska, the Aleutian Islands, and Nunavut found broad dietary similarities between dogs and humans (Coltrain et al., 2004; McManus-Fry et al., 2018; West and France, 2015) and we anticipated similar results in Labrador. The skeletal remains of marine mammals dominate faunal assemblages throughout the coastal region (Brandy, 2013; Elliott, 2017; Swinarton, 2008; Woollett, 2003), and we expected that dog diets would carry strong marine stable isotope signatures indicative of marine protein-based diets. However, as the distribution of marine species is uneven between the north and south coasts, we could not rule out geographic differences in dog diets among coastal regions. To that end, we conducted δ^{13}C and δ^{15}N analysis on the skeletal remains of dogs from north, central and south coast sites to determine, 1) Was there geographic variation in the types of foods fed to dogs? and, 2) How did the diets of dogs at Double Mer Point compare to archaeological and zooarchaeological evidence for human subsistence activities at the site? To facilitate our interpretation of dog diets, we also developed the first archaeological isotope baseline for Labrador using the skeletal remains of wild animals collected from Inuit and Basque sites.

2. Materials

Domestic dogs were identified using the comparative collection of Memorial University of Newfoundland (Swinarton, 2008). Where possible, we sampled the same skeletal element to ensure that no dogs were sampled twice, but we also relied on element size, archaeological site context, and isotope values (SI Table 2) to distinguish individuals. Given that sled dog lives were relatively short (Woollett, 2003), and we primarily sampled long bones or mandibles (avoiding alveolar bone), the sampled elements should have broadly similar collagen turnover rates. In addition to domestic dog skeletal remains, each of the sites in our study (except the Red Bay sites) produced archaeological evidence of dog sled traction in the form of dog harness and sled components (Bohms, 2018; Elliott, 2017; Fay, 2016; Rankin, 2015). While none of the sampled bones featured pathology suggestive of dog sledding (which occurs mainly on the vertebrae, maxillae, and crania [e.g. Losey et al., 2014; Park, 1987]), given the importance of dog sledding to historical Labrador Inuit culture (Section 1.2), it is likely that the sampled dogs played a role in traction.

We sampled six dogs from the pre/proto-contact site of Nachvak Village; five dogs from the post-contact communal house site of Kongu; four dogs from the communal house site of Khernertok; five dogs from the communal house site of Pigeon Cove; and 10 dogs from the communal house site of Huntingdon Island 5. In addition to sampling 22 dog mandibles from Double Mer Point, we also sampled mandibular canine dentine from four individuals. The deciduous dentition of domestic dogs begins to erupt between three and four weeks of age (Shabestari et al., 1967) and weaning begins shortly afterwards. The permanent canines begin to form below the gumline while the deciduous canines are still in situ (Shabestari et al., 1967). The permanent canine erupts between four and five months of age but at this time the root of the canine has not yet closed. In their analysis of a permanent premolar from the Mesolithic Blick Mead dog, Rogers et al. (2019) assumed that following the eruption of the premolar, it would take approximately seven weeks for the root apex of the tooth to close. We were unable to find similar data for the canine but given the size of the tooth relative to dog premolars, it may take longer for the root to close. We anticipate that following the eruption of the canine, the root will continue to grow for at least another seven weeks and thus the entire tooth may incorporate dietary information over approximately the first seven months of life.

We included nine canid specimens that could only be identified as dog/wolf under the assumption that domestic dogs could be distinguished isotopically from wild canid species due to the consumption of significant amounts of marine protein. We obtained wild faunal samples from each site except Huntingdon Island 5, and included two shipwreck contexts associated with the Basque whaling site of Red Bay. Further site context and sampling details are presented in SI File 1 and summarized in Fig. 2.

3. Methods

3.1. Collagen extraction

The collagen samples were prepared at four laboratories: The Memorial Applied Archaeological Science lab (MAAS) of Memorial University (MUN), the Archaeological Research Laboratory of

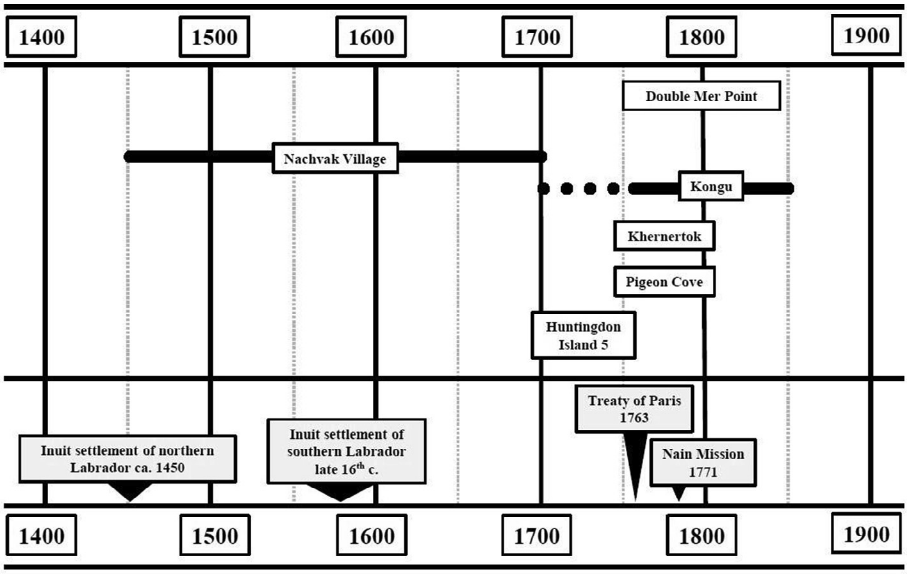

Fig. 2. A timeline of key events in Labrador history mentioned in the text (grey boxes) with approximate date ranges for each Inuit sample site (white boxes). All dates are given as AD.

Stockholm University (SU), BioArCh of the University of York, and at the Department of Anthropology of the University of British Columbia (UBC). Each collagen extraction procedure used similar modifications of the Longin (1971) method. Bone chunks of ~200 mg were cut from skeletal elements using a hand-held Dremel tool. The bone chunks were demineralized in chilled (MAAS, SU) or room temperature (UBC) 0.5 M hydrochloric acid. Additional pretreatment steps were employed to remove humic contaminants. The demineralized bone samples from Huntingdon Island and Double Mer Point were placed in chilled 0.025 M sodium hydroxide (NaOH), and the NaOH solution was refreshed at 10-minute intervals until the solution remained clear, after which time the bone samples were rinsed with 0.1 M HCl, and then rinsed to neutrality with deionized water. No sample was exposed to NaOH for longer than 40 min. The bone samples from the Red Bay shipwreck contexts were soaked in 0.1 M NaOH in a sonic bath and the solution was refreshed every 15 min until the solution remained clear. The samples were then rinsed to neutrality with Type 1 water. Gelatinisation procedures were similar across all labs: the demineralized bone samples were placed in a dilute HCl solution (pH 3) and heated to 70 °C. After 48 h, the samples were removed from heat and filtered with E-Zee filters (pore size 40–90 µm, Elkay, UK). Filtered samples were then frozen and lyophilised. Gelatinized samples from Red Bay were centrifuged to isolate solubilised collagen from solids, and frozen and lyophilised. The mandibular canines from Double Mer Point were sectioned in half, parallel to the growth axis, using a diamond-bladed bandsaw. From one half of the tooth, we cut a small wedge of dentine, of approximately 30 mg, 5 to 8 mm beneath the crown for isotopic analysis. The canine samples were demineralized in chilled 0.6 M HCl, gelatinized (80 °C, 48 h), filtered with E-Zee filters, frozen and lyophilised.

3.2. Stable isotope analysis of collagen samples

The collagen stable isotope data were obtained from four laboratories: The TERRA Facility of the CREAIT Network, Department of Earth Sciences of MUN, UBC, BioArCh, and a commercial laboratory, IsoAnalytical (IA). The samples were calibrated to the V-PDB (carbon) and AIR (nitrogen) scales using standard reference materials. The instrumentation and standards for each laboratory are presented in SI File 2. We calculated analytical accuracy, precision, and uncertainty using the methods of Szpak et al. (2017a). These calculations are presented in SI Table 1. Analytical accuracy was better than ± 0.3‰ for δ^{13}C measurements and ± 0.2‰ for δ^{15}N measurements. Analytical precision was less than ± 0.1‰ for δ^{13}C measurements and ± 0.2‰ for δ^{15}N measurements. Total analytical uncertainty could only be calculated for BioArCh and UBC and was better than ± 0.2‰ for δ^{13}C and δ^{15}N measurements. Using this method, we could not calculate analytical accuracy or total uncertainty for the samples analysed at Iso-Analytical, but the maximum differences between the measured and accepted values of the calibration and check standards included in the run were 0.1‰ for δ^{13}C and 0.2‰ for δ^{15}N. Collagen preservation was assessed by using the atomic C/N ratios and weight percent carbon and nitrogen of the combusted samples (van Klinken, 1999).

3.3. Statistical analysis

Statistical analyses were conducted with SPSS v. 23. Extreme outliers were identified as data points exceeding 3× the interquartile range as calculated using Tukey's Hinges. We were unable to compare the distribution of δ^{13}C and δ^{15}N values between sites due to inconsistent and small sample sizes, but we did compare the distribution of δ^{13}C and δ^{15}N values between dogs from the Double Mer Point houses 2 and 3 using Mann-Whitney U tests with an alpha of 0.05.

3.4. Palaeodietary modelling

We estimated the contribution of three protein sources to dog diets using SIMMR (Parnell et al., 2010, 2013) in R v. 3.5. Stable isotope mixing models estimate the relative contributions of dietary sources to an isotope mixture (the consumer) but produce a range of estimates rather than a unique solution. The number of dietary sources available to a consumer tends to exceed the number of isotope ratios that can be measured which leaves the model mathematically underdetermined, but Bayesian models, such as SIMMR, constrain some of this uncertainty by assigning probabilities to the range of possible solutions (Parnell et al., 2010). The accuracy of a model depends on appropriate trophic discrimination factors and accurate identification and isotopic characterization of the food sources (Parnell et al., 2010). We limited the number of dietary sources to three (Table 1) as there was considerable overlap in the isotopic values of different prey taxa. For example, the mean marine mammal δ^{13}C and δ^{15}N values (Table 1) are nearly identical to published archaeological codfish data (δ^{13}C:

Table 1
The mean δ^{13}C and δ^{15}N values of food groups used in the SIMMR palaeodietary model.

Food group	N	Mean δ^{13}C (‰)	SD	Mean δ^{15}N (‰)	SD
Marine mammals	44	−14.1	1.0	+15.7	1.5
Fish	241	−15.9	0.6	+10.2	0.7
Caribou	8	−18.4	0.4	+2.5	0.7

−14.5 ± 0.6‰; δ^{15}N: +15.2 ± 0.6‰) from Newfoundland (Guiry et al., 2012). Only the dog bone collagen data were included as isotope mixtures.

The marine mammals group included ringed, harp, harbour and bearded seals, and baleen whales. The fish group included published data from the bones of modern Arctic char, scales of Atlantic salmon, and muscle tissue of capelin, corrected for the Suess effect. While fish bones are not generally well-preserved at Labrador archaeological sites (Whitridge, 2001; Woollett, 2007), these species were chosen based on modern ethnographic reports of dog provisioning practices (e.g. Ames, 1977), and the proximity of Double Mer Point, Nachvak Village and Kongu to productive salmon and Arctic char rivers. The third group consisted of caribou. We grouped the dog isotope data by site and removed one extreme outlier (3x IQR) from the Double Mer Point dataset and one data point from the Huntingdon Island 5 site that fell within 0.1‰ of being an extreme outlier. We assigned trophic discrimination factors of +1 ± 0.2‰ and +4 ± 1‰ for carbon and nitrogen, respectively, after Darimont and Reimchen (2002), McManus-Fry et al. (2018), and Bocherens and Drucker (2003). We adjusted the δ^{13}C values of muscle from modern capelin collected from coastal Newfoundland (Sherwood and Rose, 2005), Iceland (Thompson et al., 1999), and Greenland (Marcoux et al., 2012) by +2.7‰ and the δ^{15}N values by −1.2‰ which reflect published muscle-collagen isotopic offsets for fish (Dury et al., 2018; Robson et al., 2012). We corrected the modern fish data, including the modern salmon scale data from Newfoundland and Labrador, for the Suess Effect using the equation below, after Hilton et al. (2006), and as modified by Misarti et al. (2009):

$$\text{Suess Effect Correction Factor(SECF)} = a * \exp^{(b*0.027)}$$

where a is the maximum annual rate of decrease in the δ^{13}C of the global oceans, estimated by Eide et al. (2017) to be −0.016‰; b is the difference between the year of death/collection and CE 1850, and 0.027 represents the exponential curve established by Gruber et al. (1999) for the change in the δ^{13}C of the global oceans between 1945 and 1970. The SECF ranged from a minimum of −0.8‰ for capelin collected in 1995 (Thompson et al., 1999) to a maximum of −1.3‰ for Arctic char collected in 2014 (Guiry et al., 2016a, b). These corrections are consistent with those of Mackensen (2013) for the Arctic Ocean. We evaluated the performance of the SIMMR model by comparing the breadth of the credible intervals for each food source, and by using matrix plots to refine our interpretation of the model results. Strong negative or positive correlations indicate that the model could not distinguish the contributions of different sources (Parnell and Inger, 2019).

4. Results

The δ^{13}C and δ^{15}N values of dogs and dog/wolf specimens from each site are presented in full, with accompanying collagen quality indicators, in SI Table 2. The isotope data from local faunal specimens are presented in SI Table 3. Four of the dog and faunal sample atomic C/N ratios exceeded 3.6 and were excluded from further analyses. The bone samples treated with NaOH had slightly lower mean C/N ratios (n = 75, 3.20 ± 0.20) than those not treated (n = 66, 3.33 ± 0.08). This suggests that NaOH may remove non-collagenous contaminants more effectively than pre-treatment methods that do not incorporate an alkaline wash (Szpak et al., 2017b), but such a small change is unlikely to make an interpretable difference in the stable isotope values of this particular dataset.

4.1. *Wild fauna*

The distribution of the δ^{13}C and δ^{15}N values of wild fauna (Fig. 3) was consistent with published isotope data from other Arctic and Subarctic contexts (Britton et al., 2013; Coltrain et al., 2004; Guiry et al., 2012; Harris et al., 2019; McManus-Fry et al., 2018; Szpak et al., 2017c). The lowest δ^{13}C and δ^{15}N values were measured in small terrestrial herbivores, ptarmigan and hares. Eight caribou had mean δ^{13}C and δ^{15}N values of −18.4 ± 0.4‰ and +2.5 ± 0.7‰, respectively. Harp, ringed, and bearded seals had similar δ^{15}N values of ~ +15.5‰, but we found some slight differences in the δ^{13}C values among seal species. Harbour seals had δ^{15}N values that were approximately +2‰ higher than those of other seal species. Baleen whales had slightly lower δ^{13}C and δ^{15}N values, reflecting their consumption of low trophic level invertebrates (Lowry, 1993).

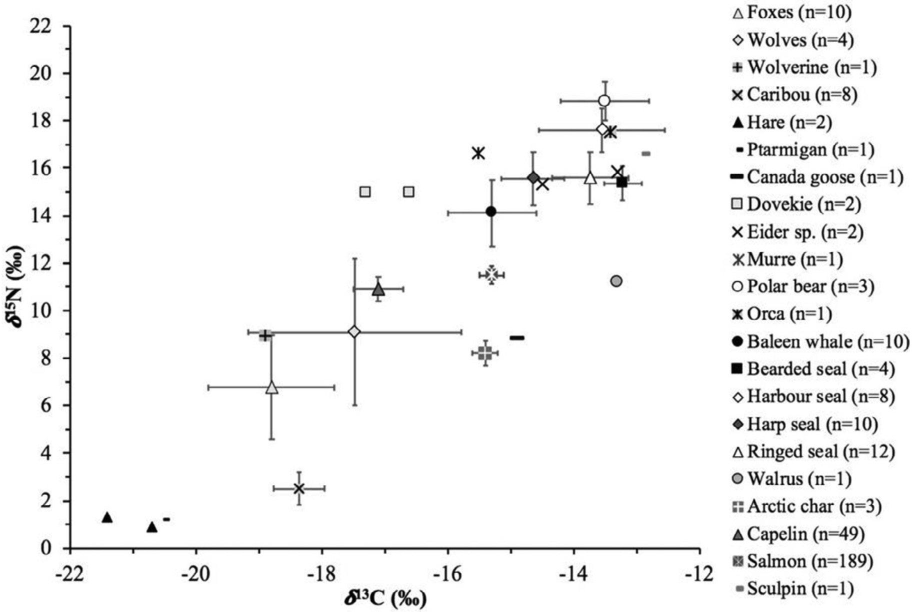

Fig. 3. Baseline δ^{13}C and δ^{15}N values of wild fauna from Labrador. Published isotope data from Arctic char (Guiry et al., 2016a, b) and salmon scale collagen (Dixon et al., 2012) and capelin muscle tissue, corrected to bone collagen values (Marcoux et al., 2012; Sherwood and Rose, 2005; Thompson et al., 1999) added for comparison.

By using the isotopic data from foxes and wolves we can estimate the types of foods that would be available to dogs without direct provisioning by Inuit, while polar bears represent diets that are known to be dominated by marine mammals (Cherry et al., 2011; Thiemann et al., 2008). Arctic and red foxes had overlapping δ^{13}C and δ^{15}N values, ranging from −19.8‰ to −17.1‰ (mean −18.7 ± 1.1‰), and +3.3‰ to +10.4‰ (mean +6.9 ± 2.5‰). Consistent with ecological observations, the foxes with δ^{15}N values approaching +10‰ may have eaten some marine or anadromous protein. Foxes are known to hunt for seabird eggs, denning ringed seal pups, and scavenge polar bear kills in Labrador, Newfoundland, Iceland, and northern Norway (Andriashek et al., 1985; Angerbjörn et al., 1994; Roth, 2002; Sklepkovych, 1986). The four wolf specimens had δ^{13}C values ranging from −18.8‰ to −15.0‰ (mean −17.5 ± 1.7‰), and δ^{15}N values ranging from +7.0‰ to +13.5‰ (mean 9.1 ± 3.0‰). The two wolf specimens from Pigeon Cove had δ^{13}C values and δ^{15}N values that differed by 0.3‰ and 0.1‰, respectively, suggesting only one individual is represented. The range in wolf δ^{13}C and δ^{15}N values can be attributed to the high δ^{13}C and δ^{15}N values of the specimen from Huntingdon Island 5. Wolves in British Columbia and Alaska are known to opportunistically take spawning salmon, or scavenge marine mammals (Darimont and Reimchen, 2002; Milakovic and Parker, 2011). Isotopic compositions ($n = 22$, $\delta^{15}N = 10.8 \pm 1.6$, $\delta^{13}C\ -15.3 \pm 0.8$ (Guiry et al., 2016a, b)) of archaeological Atlantic salmon which are comparable across their range (Guiry, 2019), are consistent with this possibility. Archaeologists also observed wolves and their tracks along the shore of the mainland adjacent to Huntingdon Island during the excavation of the site. The three polar bears in our study, from Nachvak Fiord and Red Bay, had δ^{13}C values ranging from −14.1‰ to −12.7‰ (mean −13.5 ± 0.7‰), and δ^{15}N values ranging from +18.1‰ to +19.7‰ (mean +18.8 ± 0.8‰).

4.2. Domestic dogs and dog/wolves

The specimens identified as *Canis* sp. or dog/wolf (n = 9) had δ^{13}C values ranging from −19.9‰ to −12.4‰ and δ^{15}N values ranging from +5.3‰ to +21.3‰. All but one of the dog/wolf specimens grouped with the domestic dogs (Fig. 4), suggesting that in Labrador, isotopic composition may be used as a robust indicator of domestication status based on the premise that dogs were provisioned with foods that are typically less available to their non-domestic counterparts. The dog/wolf specimens that isotopically grouped with domestic dogs from each site were combined for subsequent analysis (Table 2). We observed some geographic patterning between the dogs from the north, central, and south coasts of Labrador (Fig. 5) that will be explored in greater detail on a site by site basis.

Table 2
Mean δ^{13}C and δ^{15}N values of bone collagen from domestic dogs and dog/wolves from Labrador Inuit sites, presented to 1 SD. The interquartile ranges (IQR) were calculated using Tukey's Hinges and were used to identify outliers (3xIQR).

Site	N	δ^{13}C	SD	IQR	δ^{15}N	SD	IQR
Double Mer Point	19	−13.3	0.8	0.6	+18.3	1.5	1.3
Nachvak Village	6	−14.2	0.2	0.2	+16.5	1.2	1.3
Kongu	6	−13.4	0.6	0.9	+17.7	0.8	1.1
Khernertok	5	−13.4	0.2	0.2	+16.8	0.5	0.9
Pigeon Cove	5	−13.7	0.5	0.6	+18.4	0.7	1.2
Huntingdon Island 5	11	−13.5	0.6	0.5	+18.9	0.7	1.2

The δ^{13}C values of dogs from the north coast sites (Nachvak Village, Kongu and Khernertok) ranged from −14.6‰ to −12.7‰ (mean −13.8 ± 0.5‰), and the δ^{15}N values ranged from +14.6‰ to +18.4‰ (mean +16.9 ± 0.9‰) (Fig. 6). The dogs from House 2 at Khernertok form a tight cluster, and two of the five samples (MARC 2004 and 2063) may represent the same individual.

We obtained well-preserved collagen from 19 of the 22 mandibles and from the four canines from Double Mer Point. The δ^{13}C values of the dog bone collagen range from −15.6‰ to −12.4‰ (mean −13.4 ± 0.8‰), and the δ^{15}N values range from +14.2‰ to +21.3‰ (mean +18.3 ± 1.5‰) (Fig. 7). One dog, DMP 11, had an outlying δ^{13}C value of −15.6‰ and a relatively low δ^{15}N value of +14.2‰, suggesting that it was fed differently than the majority of the dogs from the site. The dogs recovered from the barrier between Houses 1 and 2, potentially dating to the early 19th century, had higher mean δ^{13}C (−12.9 ± 0.6‰) and δ^{15}N (+19.4 ± 1.2‰) than the dogs from Houses 2 and 3 which had similar mean δ^{13}C and δ^{15}N values. The dogs from House 2 had the most variable δ^{13}C and δ^{15}N values, with SDs of 0.9 and 1.9, respectively, but no statistically significant differences were noted between the δ^{13}C ($U = 26.5$, $p = 0.384$), or δ^{15}N ($U = 30.5$, $p = 0.631$) values of dogs from House 2 or 3.

The stable isotope values of the mandibles and mandibular canines

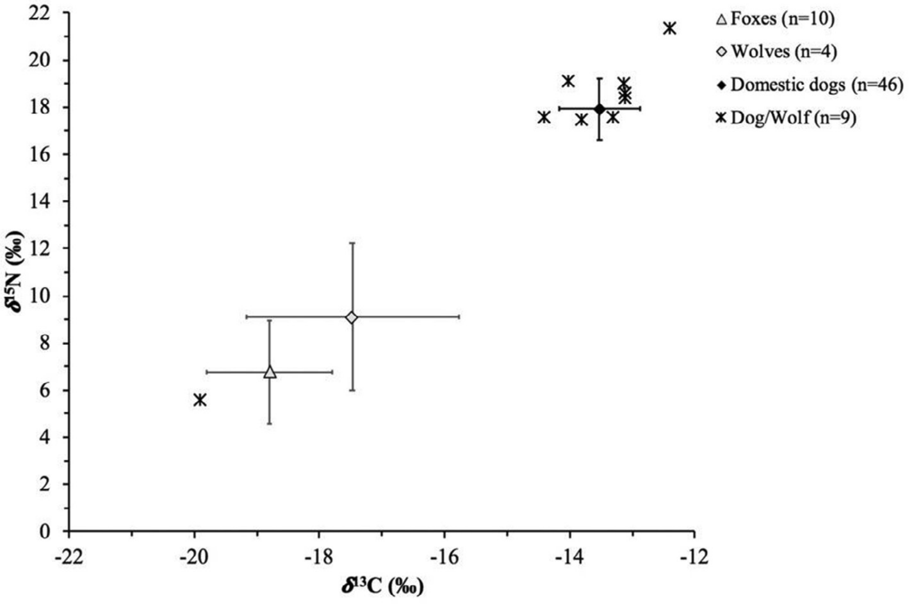

Fig. 4. Mean δ^{13}C and δ^{15}N values of fox, wolf, and domestic dogs from coastal Labrador plotted with specimens identified as "Dog/wolf".

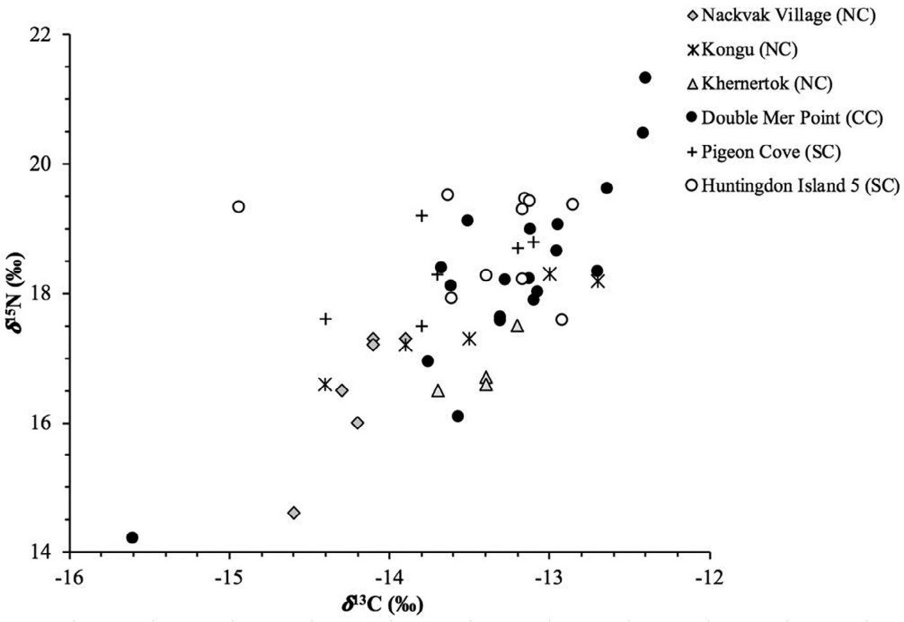

Fig. 5. Dog and dog/wolf bone collagen samples presented by site.

of four dogs are compared in Table 3. The offset in $\delta^{13}C$ values between the paired samples from DMP04, 17, and 24, did not exceed ± 0.1‰. The canine $\delta^{15}N$ values were high relative to mandibular values, with $\Delta^{15}N_{C\text{-}M}$ ranging from +1.0‰ to +1.6‰. A negative offset of −0.7‰ occurred between the $\delta^{13}C$ values and of −1.5‰ between the $\delta^{15}N$ values of the canine and mandible of DMP02.

The 17 specimens from the sites in Sandwich Bay had $\delta^{13}C$ values ranging from −14.9‰ to −12.9‰ (mean −13.5 ± 0.6‰), and $\delta^{15}N$ values ranging from +17.5‰ to +19.5‰ (mean +18.7 ± 0.7‰), (Fig. 8). The distribution of $\delta^{13}C$ values was similar between Pigeon Cove and Huntingdon Island 5, however one dog from Huntingdon Island 5 had a relatively low $\delta^{13}C$ value of −14.9‰.

SIMMR estimates of the proportions of three food sources to dog diets are presented in Figs. 9 and 10. The summary quantiles are presented in SI File 3. The credible intervals were the narrowest for caribou, but the mean and median estimates showed good agreement for all food sources and all of the standard deviations fell below 0.15 with the majority less than 0.10.

Across all sites, the relative proportions of fish and marine mammals were negatively correlated (−0.9) indicating that either fish or marine mammals composed the primary contribution to diet, but both could not have contributed equally over the time span represented by bone collagen (Inger et al., 2015). The model could not distinguish the relative contributions of sources to the diets of Nachvak Village dogs, as indicated by negative correlations between fish and caribou (−0.8) and between fish and marine mammals (−0.9). Consistent with our preliminary interpretation of the stable isotope data marine mammals were the greatest contributor to diet across all sites. Dogs of the central and south coast sites consumed the greatest proportion of marine mammals with very minor contributions from caribou and fish, while dogs at Nachvak Village and Khernertok likely ate a significant amount of fish and/or caribou in addition to marine mammals.

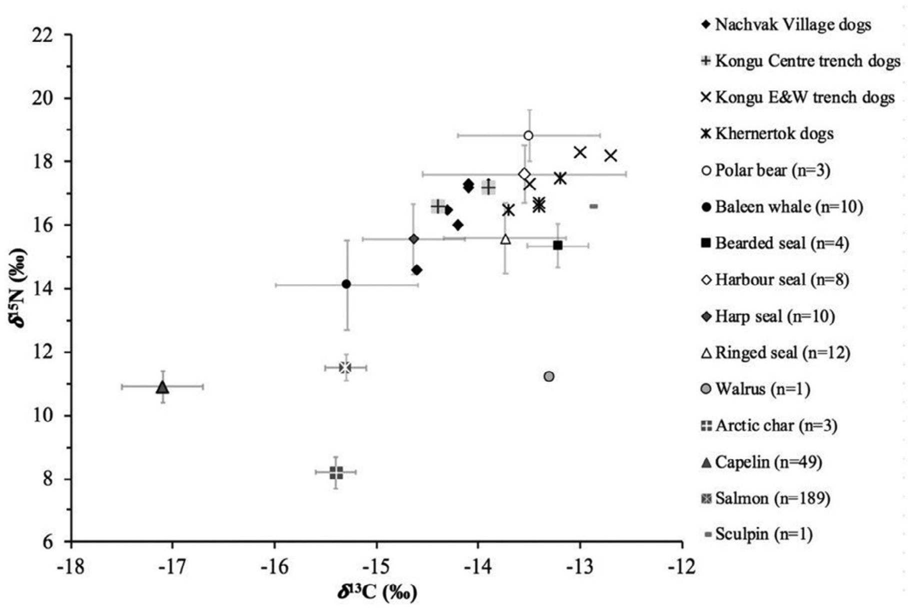

Fig. 6. The $\delta^{13}C$ and $\delta^{15}N$ values of domestic dogs from Nachvak Village, Kongu, and Khernertok plotted with possible food sources. Published isotope data from Arctic char bone (Guiry et al., 2016a, b), salmon scale collagen (Dixon et al., 2012) and corrected capelin muscle tissue (Marcoux et al., 2012; Sherwood and Rose, 2005; Thompson et al., 1999) added for comparison.

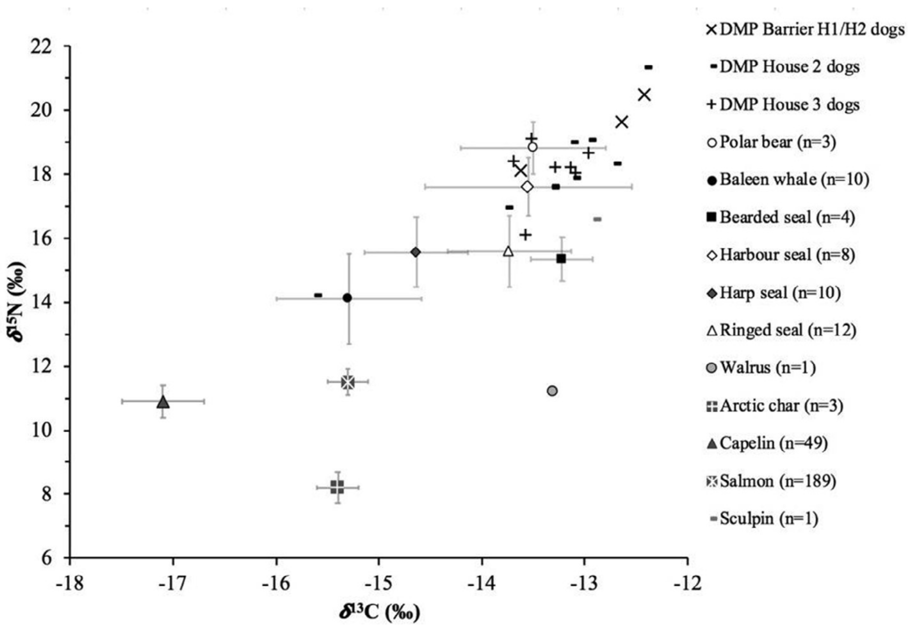

Fig. 7. The δ^{13}C and δ^{15}N values of Double Mer Point dogs, separated by house, plotted with possible food sources. Published isotope data from Arctic char bone (Guiry et al., 2016a, b), salmon scale collagen (Dixon et al., 2012) and capelin muscle corrected to bone collagen values (Marcoux et al., 2012; Sherwood and Rose, 2005; Thompson et al., 1999) added for comparison.

Table 3
Double Mer Point mandibular and canine δ^{13}C and δ^{15}N values, and the offsets between the canine (C) and mandible (M).

Sample ID	Element	δ^{13}C	$\Delta^{13}C_{C\text{-}M}$	δ^{15}N	$\Delta^{15}N_{C\text{-}M}$
DMP02	Mandible	−12.4		+20.5	
	Canine	−13.1	−0.7	+19.0	−1.5
DMP04	Mandible	−12.6		+19.6	
	Canine	−12.5	+0.1	+20.6	1.0
DMP17	Mandible	−13.5		+19.1	
	Canine	−13.6	−0.1	+20.7	1.6
DMP24	Mandible	−13.1		+18.0	
	Canine	−13.0	+0.1	+19.4	1.4

5. Discussion

5.1. Palaeodietary analysis of Labrador sled dogs

Through the analysis of dog diets, we can better understand the subsistence activities required to provision sled dogs and facilitate Inuit mobility and trade in coastal Labrador between the 15th and 19th centuries. Sled dog diets were dominated by marine mammal protein, but the possibility that codfish may have played a minor role in dog diets cannot be excluded based on the similarity between the isotopic composition of codfish and marine mammals. Regional variation occurred among dog diets that may have been rooted in the geographic distribution of Inuit habitations and land use patterns relative to that of prey species. For example, Nachvak Village is situated within easy reach of navigable routes to inland caribou herds, and while poor bone preservation conditions may have differentially impacted fish remains, the site is located next to a famously productive Arctic char river. Dogs may have been partially provisioned, perhaps in the warm months when they were not working, with locally available caribou and fish. Working sled dogs require at least 10 000 calories per day and thrive when > 50% of those calories are sourced from fat, most easily acquired from blubberous marine mammals (Case et al., 2000; Kuhnlein et al., 1991; Loftus et al., 2014). With mean δ^{13}C and δ^{15}N values of −14.2‰ and +16.7‰, respectively, the Nachvak Village dogs may

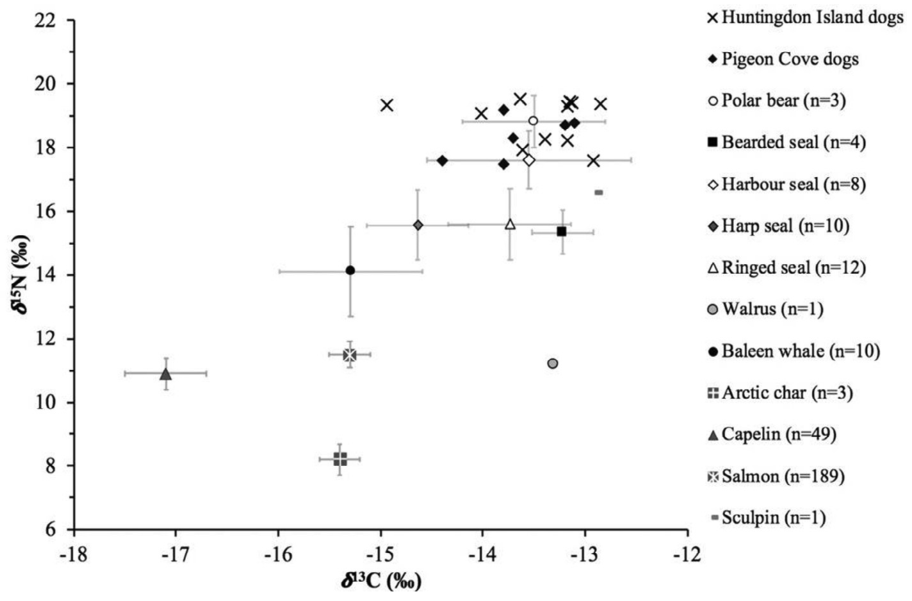

Fig. 8. The δ^{13}C and δ^{15}N values of domestic dogs from Huntingdon Island and Pigeon Cove plotted with possible food sources. Published isotope data from Arctic char bone (Guiry et al., 2016a, b), salmon scale collagen (Dixon et al., 2012) and capelin muscle corrected to bone collagen values (Marcoux et al., 2012; Sherwood and Rose, 2005; Thompson et al., 1999) added for comparison.

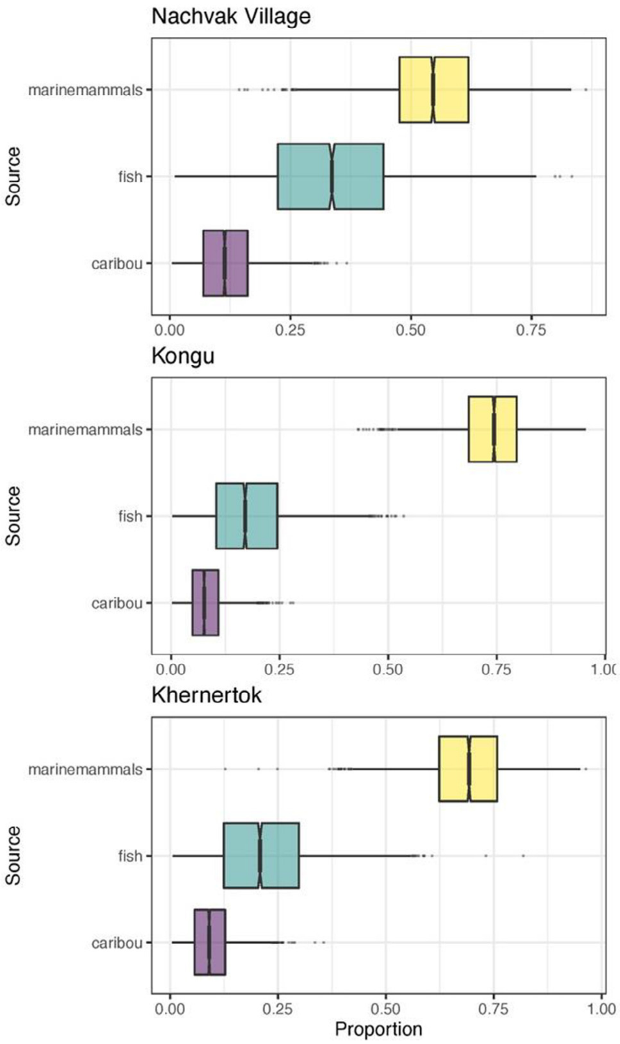

Fig. 9. Bayesian estimates of the proportions of protein types for north coast sites: Nachvak Village (n = 6), Kongu (n = 6), and Khernertok (n = 5).

have received approximately half of their protein from marine mammals. This is in contrast to dogs from the east and west trenches of Kongu which were provisioned largely with marine mammals year-round. These dogs, associated with the middens of two communal houses, had higher δ^{13}C values than dogs from the trench associated with the possible older feature. The centre trench at Kongu may relate to the earliest Inuit occupation of the site, by former residents of Nachvak Village (Elliott, 2017), so the lower isotopic values of the centre trench dogs may reflect foods obtained from the environment around Nachvak Village. Due to insufficient evidence, we are unable to say with certainty that the difference between Nachvak Village and the communal houses of Kongu was not due to broad changes in Inuit subsistence practices over time due to factors such as climate and shifting economic foci. Kaplan (1983) found that seal and whale were consistently important across outer coastal sites in Northern Labrador and Woollett's (2003) analysis of subsistence over ~300 years of Inuit occupation in Hamilton Inlet found little change in types of prey targeted until the mid-19th century, when inland trapping became an important economic activity.

The sled dogs at Khernertok consumed similar diets to one another, but with a mean δ^{15}N value of +16.8‰, similar to Nachvak Village dogs, and were fed less seal than dogs at Kongu or at sites further south. At −13.4‰, the mean δ^{13}C value is high relative to fish (−16.3‰) and caribou (−18.3‰) making it unlikely that the diets of Khernertok dogs were supplemented with caribou or Arctic char to the same extent as Nachvak Village dogs. Archaeological walrus in the Eastern Arctic have low δ^{15}N values (~ +12‰) relative to seals and δ^{13}C values of approximately −13‰ (Coltrain et al., 2004; Nelson et al., 2012), and when compared with dog isotope values, may have been a source of protein at Khernertok.

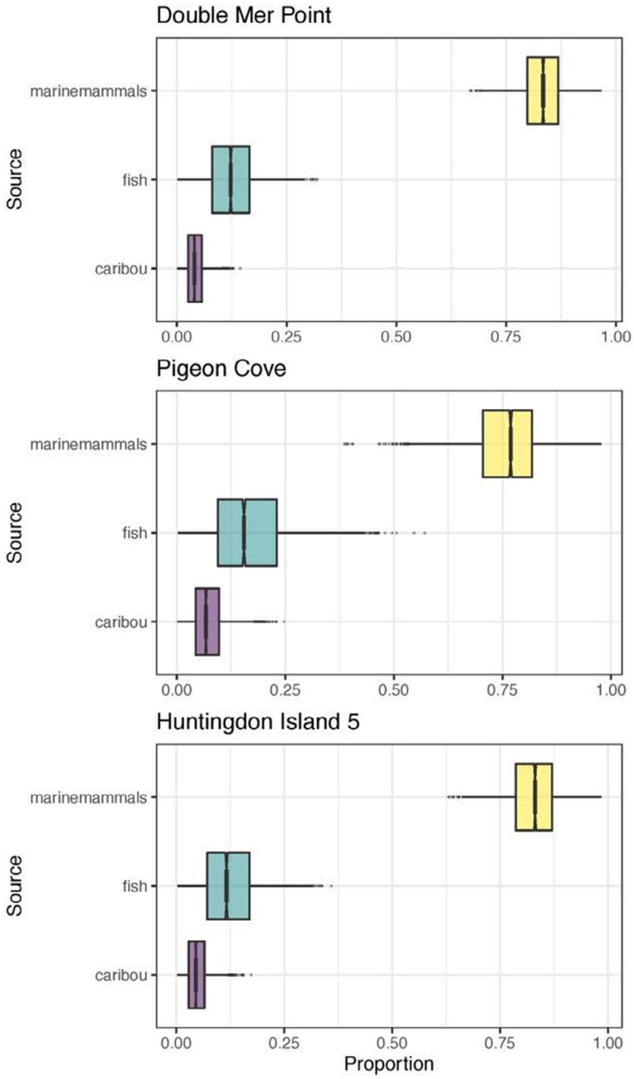

Fig. 10. Bayesian estimates of the proportions of protein types for central and south coast sites: Double Mer Point (n = 19), Pigeon Cove (n = 6), and Huntingdon Island 5 (n = 11) dogs.

The diets of dogs from Huntingdon Island 5 and Pigeon Cove were dominated by marine mammals, most likely seal. Huntingdon Island 5 lies adjacent to a polynya where seals could have been hunted in the winter and the Inuttitut name for Sandwich Bay translates as the Place of Many Ringed Seals (Rankin, 2015). Seal were important throughout the occupation of Huntingdon Island 5 and featured prominently in the middens from Houses 3 and 4 (Brandy, 2013; Rankin, 2015).

5.2. Dog provisioning at Double Mer Point

Double Mer Point is located in one of the best studied regions of Labrador and is almost fully excavated giving us the opportunity to contextualize the isotopic data with archaeological and zooarchaeological evidence. The domestic dogs at Double Mer Point were provisioned with marine foods with minor contributions from sources such as Arctic char, Atlantic salmon, or caribou. Jordan and Kaplan (1980) observed that ringed and harbour seals negatively covary in faunal assemblages from Hamilton Inlet and harbour seals may have been more commonly hunted during the 18th century (Woollett, 1999). This may have occurred at other sites in Hamilton Inlet, but is unlikely at Double Mer Point. With several exceptions, the majority of the dogs have δ^{15}N values falling at or below the mean harbour seal δ^{15}N value. These values are consistent with diets of ringed or harp seals and align with the site's zooarchaeological assemblage, which predominantly features ringed and harp seal (Elliott and Swinarton, in press). Ringed seals could be hunted during the winter in the open water off the coast of Double Mer Point, or caught denning in the ice of Double Mer to the north and west of the site.

The paired canine and mandible samples taken from four dogs recorded a change in diet that may relate to seasonal availability of food resources. As the permanent canine begins to form between one-three months after weaning (Shabestari et al., 1967), it should not be strongly influenced by a nursing isotope signal. The positive $\Delta^{15}N_{C\text{-}M}$ and negligible $\Delta^{13}C_{C\text{-}M}$ observed for three dogs suggests that as the canine root grew, the three dogs were consuming higher trophic level food than was reflected in mandibular bone collagen. Puppies born in the early spring could have been fed the meat of ringed or harbour seals (including juveniles of both species), seabirds and their eggs, and later, in the summer, they may have been provisioned with salmon or capelin (Ames, 1977). Several months of eating the meat of adult and juvenile seals may have elevated canine δ^{15}N values relative to the average sources of dietary protein throughout the year which would be recorded in mandibular collagen. We observed negative $\Delta^{15}N_{C\text{-}M}$ and $\Delta^{13}C_{C\text{-}M}$ for a fourth dog which suggests a diet composed of lower trophic level foods, like fish or caribou, during puppyhood followed by increasing contributions of seal meat later in life.

While there were no significant differences in the mean isotope values between dogs from Houses 2 and 3, the dogs from House 2 had more variable isotope values which may relate to Inuit trading activities. The human occupants of House 2 had more European manufactured goods and may have been heavily involved in coastal trade networks (Bohms, 2018; Jankunis, 2019) which could have necessitated travel throughout the year (Fay, 2015). During long-distance trips, sled dogs could be exchanged or purchased, or could perish at sites far from their place of birth. A dog (DMP11) with stable isotope values consistent with a mixed diet of fish, seal and caribou may have originated from the north coast where such diets appear more common. Another dog (DMP06) with a δ^{13}C value of -12.4‰ and δ^{15}N value of $+21.4$‰ was provisioned with very high trophic level foods, or perhaps shallow water fish, which may indicate access to a different resource base than was available at Double Mer Point.

Palaeodietary studies rely on the tested assumption that bone collagen predominantly reflects the isotopic composition of dietary protein (Ambrose and Norr, 1993; Fernandes et al., 2012; Froehle et al., 2010; Tieszen and Fagre, 1993) and cannot be used to effectively study sources of dietary fat. By measuring the δ^{13}C values of blood and lipids, Cherry et al. (2011) showed that polar bears obtained dietary protein from ringed and other small species of seal, while large species of seal, whale, and walrus contributed significant amounts of dietary energy that would have been invisible through the analysis of polar bear proteins alone. We might find similar results were we to analyse dog bone lipids, or the δ^{13}C values of amino acids synthesized from non-protein carbon sources and would be better positioned to speak to past dog husbandry practices among Labrador Inuit.

We did not identify any clear isotopic markers of nutritional or physiological stress (e.g. negatively covarying δ^{13}C and δ^{15}N values [Beaumont and Montgomery, 2016]) among the sampled dogs, but this possibility should be considered in future studies of sled dogs. Reduced or intermittent summer feeding of dogs has been documented ethnographically (Boas, 1974), and suggested by osteological evidence (Losey et al., 2014). Physiological stress may be possible in dogs that carry a heavy intestinal parasite load due to the ingestion of contaminated animal meat, including that of other dogs (Cameron et al., 1940; Connell, 1949; Goyette et al., 2014; Salb et al., 2008). Further studies employing incremental sampling protocols may identify episodes of dietary or physiological stress in dogs that could be further investigated through parasitological or proteomic/genetic analyses of dog coprolites recovered from Inuit sites.

6. Conclusion

The δ^{13}C and δ^{15}N values of dogs and wild fauna from coastal Labrador form the first investigation of dog provisioning practices of Labrador Inuit and act as a complimentary line of evidence for understanding dog husbandry in Eastern Canada. There was some geographic variation in the types of foods that dogs could access between sites. All dogs consumed marine mammals, but dogs on the north coast were additionally provisioned with fish, caribou, and potentially walrus. Caribou and Arctic char were accessed at the site of Nachvak Village, but the predominance of marine mammals in the diets of dogs confirms the importance of these animals to the performance of working dogs in cold environments. To the south, the diets of dogs closely aligned with the zooarchaeological assemblages, suggesting that humans and dogs subsisted on similar protein sources, such as ringed seal. This does not represent a complete picture of diet, however, as lipids may have contributed upwards of 50% of the calories in dog diets, and Inuit may have consumed imported European goods, such as salt pork or flour, that would not have been given to dogs.

Double Mer Point was situated within a productive environmental region where seals could be hunted year-round, and local dogs predominantly ate small species of seal (ringed and harp), but with some minimal seasonal variation in the trophic level of prey. The human occupants of House 2 were heavily involved in coastal trade networks and this may be reflected in the dietary variation of dogs recovered from the house. Our analysis of paired mandibular and canine samples yielded evidence for seasonal variation in dog diets and suggests the potential of future applications of this method to understand dog provisioning in seasonal environments.

CRediT authorship contribution statement

Alison J.T. Harris: Conceptualization, Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Deirdre A. Elliott:** Writing - original draft, Writing - review & editing. **Eric J. Guiry:** Methodology, Writing - original draft, Writing - review & editing. **Matthew Von Tersch:** Methodology, Writing - review & editing. **Lisa Rankin:** Investigation, Writing - review & editing. **Peter Whitridge:** Investigation, Writing - review & editing. **Michelle Alexander:** Supervision, Writing - review & editing. **Gunilla Eriksson:** Supervision, Funding acquisition, Writing - review & editing. **Vaughan Grimes:** Conceptualization, Funding acquisition, Supervision, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2020.102424.

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