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Thule whaling at Point Barrow, Alaska: The Nuvuk cemetery stable isotope and
radiocarbon record

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24 **Abstract**

25 Coastal erosion on the Point Barrow, AK, spit necessitated salvage excavation of the
26 Nuvuk cemetery. Purified bone collagen extracted from 54 Thule era burials was
27 analyzed for stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotopes values and accelerator
28 radiocarbon dated. The highly enriched nitrogen isotope chemistry of these burials
29 indicates the Nuvuk were apex marine predators with heavy reliance on high trophic level
30 marine taxa, primarily beluga whales and ringed and bearded seal. Bowhead whaling
31 made a less significant contribution to sampled diets despite its social currency. In
32 contrast, carbon isotope values suggest significant terrestrial inputs to Nuvuk diets.
33 Comparative data from Aleutian and eastern Arctic marine foragers further confound
34 what appear to be conflicting results. Yet modern polar bear along the Beaufort Sea shelf
35 show isotopic patterning very similar to that of the Thule at Nuvuk. We suggest that
36 depleted Nuvuk $\delta^{13}\text{C}$ values result primarily from the discharge of riverine, terrigenous
37 carbon into the Beaufort Sea during spring, freshwater runoff. The deposition of large
38 amounts of terrigenous carbon prior to the melting of landfast ice contributes to an
39 isotopically depleted estuarine-like, near-shore food web. A local ΔR correction to marine
40 reservoir effect was used to calibrate AMS radiocarbon dates. Results are supported by
41 paired two-sigma age ranges on burials and associated terrestrial grave materials.

42

43 **Keywords**

44 Nuvuk; Point Barrow, AK; Thule whaling; terrigenous carbon; stable isotope chemistry;
45 marine reservoir effect

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1. Introduction

Here we report stable isotope values and AMS radiocarbon dates on 54 Thule burials from the Nuvuk cemetery at Point Barrow, AK (Figure 1). We compare Nuvuk dietary data with like datasets from the Aleutians and eastern Arctic and pair marine reservoir corrected AMS dates on human remains with radiocarbon dates on associated funerary materials. Nuvuk burials were removed as rising sea levels eroded the sandy, unconsolidated gravels of the Point Barrow spit. Since 2000, with funding from the National Science Foundation and U.S. Department of Education, Anne Jensen (2014; 2009a, b; 2007) and colleagues have engaged in extensive testing, mapping and salvage excavation of burials from the erosion face of the spit, recovering remains otherwise lost to a rising sea. The Nuvuk village site, occupied well into the historic period, was previously lost to erosion highlighting the effects of rising sea levels along this coastline.

Until 1997 with salvage recovery of the Nuvuk 01 burial (A.D. 810-1020) (Jensen 2009a:Table 3, 2009b, 2007), it was thought that the indigenous occupation at Nuvuk was recent, a late pre-contact or more recent village, and of limited interest to prehistoric archaeologists. Since that time, extensive radiocarbon dating of wood and caribou fur in association with burials has confirmed a late first millennium A.D. time depth (Jensen 2009a, b). These data as well as the recovery of temporally diagnostic harpoon and arrow heads from Nuvuk (Jensen 2009a, b; 2007), Birnirk (Ford 1959) and Utqiagvik (Mason 1991) indicate that the Barrow region played a pivotal role in the emergence of the Thule cultural complex and was the origin of Thule migrations into the eastern Arctic early in the second millennium A.D. (McGhee 2009; Morrison 2009).

Thule village sites in the Barrow region correspond well with historic bowhead whale (*Balaena mysticetus*) sightings. Relative sedentism in contrast to previous mobile foraging strategies is indicated by the construction of well-built, sod covered winter houses with driftwood and whalebone superstructures. Dog traction was in use (McManus-Fry et al. 2016). Crescent-shaped soapstone lamps furnished heat and light. Weaponry consisted of multi-component harpoons, lances, throwing boards and the bow and arrow. Equipped with sophisticated technologies to harvest bowhead whale, dog traction, and weaponry the Thule expanded rapidly from the Barrow region east across the Canadian Arctic.

2. Background

Jensen (2014; 2009a, b) provides a comprehensive review of research and current thought on the prehistory of the Barrow region. Central to an understanding of Thule in northwest Alaska is their relationship to the Punuk and Birnirk. The appearance of the Thule cultural complex in the late first millennium A.D. appears to follow the emergence of whaling among the Birnirk under the influence of the Punuk present on both the eastern and western mainlands of the Bering Strait and on St. Lawrence and other Bering Strait islands. Attempts to establish clear geographic or temporal boundaries, either integrating or distinguishing these archaeological complexes has been based primarily on the typology of harpoon heads and has proven difficult (Harritt 2004; Hollinger et al., 2009; Jensen 2009b; Mason 2009; Morrison 2001). These attempts are further complicated by the loss of sites to coastal erosion and uncertainty regarding marine reservoir corrections to dates on temporally diagnostic artifacts (e. g., McGhee 2009). A thorough treatment of these issues is beyond the scope of this paper (see Mason 2009).

We are however in agreement with Jensen (2009a:Figure1). The Thule at Nuvuk have a deep occupational history extending into the tenth century A.D., initially contemporaneous with both the Punuk and Birnirk in the western Arctic, as well as pre-dating early Thule sites in the eastern Arctic (Jensen 2009a:Figure 1, 2009b:Figure 5). Similarities in Punuk and Thule material culture are the consequence of a shared investment in whaling but do not define the Thule as Punuk per se.

The establishment of Nuvuk and other coastal villages in the Barrow region was underwritten by bowhead whaling facilitating the acquisition of surpluses of blubber and baleen suitable for trade. The return of Bering/Chukchi Sea bowhead whale stock from summer feeding grounds in the Beaufort Sea (Hoekstra et al. 2002; Lee et al. 2005) likely interfered with the fall caribou (*Rangifer tarandus*) hunt resulting in the development of extensive trade networks between whaling villages on the northwest coast of Alaska and mobile caribou hunters in the interior. Sheehan (1995) argues that from A.D. 1200-1826 coastal whaling villages from Point Hope to Barrow traded seal oil and whale blubber for caribou skins and antler. The former provided inland hunters with a buffer against starvation when the caribou harvest was poor or lean animals were taken out of season, whereas caribou hides harvested in the fall were both pliable and warm, highly sought after for winter clothing. Ethnographic accounts record the slaughter of hundreds of animals taken seasonally for their skins alone (Burch and Blehr 1991:442). A family of seven required nearly 70 skins a year to work into mats, tent material and clothing replaced annually (Sheehan 1995:196). Caribou sinew was used for bowstrings and antler for tools, slat armor, and projectiles. Wood for floor planking was also obtained from the interior. Of like need,

inland hunters used sea mammal oil for heat, light and food preservation, as well as augmenting lipid intake with seal skin pokes of oil and blubber acquired in trade and at times vital to survival.

With the establishment of Thule whaling villages, warfare appears to figure prominently in the prehistory of the Barrow region. Mason (2012, 2009) addresses the issue with detailed reviews of the Bering Strait and northwest Alaska archaeological record concluding that material evidence for warfare is “most unambiguous from A.D. 1400-1700” (Mason 2012:72). However he cautions that historic Iñupiat accounts of endemic, early nineteenth century warfare may resonate in oral narratives of earlier conflict, inflating the intensity of prehistoric violence. Defensively positioned sites are limited in number and Thule era skeletal assemblages across the region are virtually devoid of perimortem trauma. Yet the widespread distribution of Thule slat armor (Mason 2012:Figure 1) indicates the threat of raiding or call to raid was possible if not frequent in some settings. “Slat armor was most widespread and plentiful at Barrow, Kotzebue, Cape Espenberg and Wales between A.D. 1250-1550 (Mason 2012:Figure 1), all of which supported the largest populations” (Mason 2012:83) suggesting that population growth underwritten by whaling led to a concentration of power in whaling captains and increasingly competitive interactions with the interior (see also Sheenan 1995).

Thule whaling captains likely organized trading partnerships and raiding parties. The economic role of whaling and its attendant risks conferred both status and relative wealth on successful captains incentivizing violence. Burch (1981:14-17) suggests that the heightened intensity of warfare between A.D. 1600-1850 resulted in

significant depopulation furthered by European contact. Yet the most compelling archaeological evidence for warfare occurs earlier, as cited above, following the Medieval Climate Anomaly (Jordan 2009) and broadly coincident with the onset of Neo-boreal cooling. Accordingly, declining temperatures resulted in pack ice formation earlier in the fall and the appearance of shore leads later in the spring limiting the movement of bowhead whales to and from summer feeding grounds. Since bowhead whales, “tend to follow the retreating ice margin and enter the high arctic channels only when a maximum of open water is available” (Savelle and McCartney 1988:35), an increase in summer drift-ice may also have resulted in fewer whales and less predictable migrations, reducing their encounter rate. Thus episodic acts of raiding may have increased in frequency and intensity escalating into warfare during periods of shortfall. The onset of Neo-Boreal cooling is also coeval with the movement of Thule from the Point Barrow region into the eastern Arctic early in the second millennium A.D. suggesting population pressure on the coastal, northern Alaskan resource base.

2.1. The Nuvuk cemetery site

The Thule cemetery at Nuvuk is the largest in northwest Alaska. Located on the highest beach ridge of the Point Barrow spit at the juncture of the Chukchi and Beaufort Seas, Nuvuk was ideally placed to monitor the seasonal movement of bowhead whales (Schell et al. 1988). Jenson (2009a:96) cites Charles Brower (1942:255), an Iñupiat whaler, who “refers to Nuvuk as one of the best hunting and whaling spots on the coast.” The site also affords access to the interior along river drainages discharging into Elson Lagoon encircled by the spit.

Nuvuk graves were shallow, most between 20-40 cm deep, and driftwood framed (Jensen 2009a:127-131). On occasion whalebone was used as framing material. Some individuals were covered with wood planks or in a few cases laid on planking. It also appears that others were wrapped in or laid on caribou hides, long decayed but indicated by fragments of hide and matted fur. Individuals were interred flexed on their backs, similar to both Birnirk and Neoeskimo burials across the region.

The Nuvuk 01 burial (A.D. 810-1020) was accompanied by a wealth of grave goods including numerous harpoon heads and other ivory and antler implements (Jensen 2009a:Table 3). However this early Thule burial was the exception. Grave goods were relatively rare among individuals under study, consisting of isolated items such as an ulu blade, baleen bucket or bolo weights (Jensen 2009a:135-137). Despite the near absence of grave goods, most graves contained burial rocks. Jensen (2009a:135-136) describes them as small, flat and water-worn. Larger than spit gravels, they were clearly collected and transported for this purpose.

Research was designed to reconstruct Nuvuk diets from the stable isotope chemistry of bone collagen, the protein in bone, and provide AMS radiocarbon dates on purified bone collagen in collaboration with an aDNA study conducted by Dennis O'Rourke and Justin Tackney, results of which are presented elsewhere (Tackney et al. 2016a, 2016b, 2014). Letters of permission for work with Nuvuk remains were obtained from the Native Village of Barrow Iñupiat Traditional Government, the Ukpeaġvik Iñupiat Corporation and the Barrow Senior Advisory Council.

3. Materials and Methods

Stable isotope ratios are frequently used to address the importance of marine resources in forager diets lacking a C_4 component. The technique was introduced by Tauber (1981) to demonstrate a reduction in dependency on marine resources in coastal Denmark at the Mesolithic to Neolithic transition (see also Chisholm et al. 1982). Since that time numerous studies have employed stable isotope analysis to reconstruct mixed marine/terrestrial diets (e.g., Britton et al. 2016, 2013; Coltrain 2011; 2010a, b; 2009; Coltrain et al. 2004; Guiry et al. 2015; Laffoon et al. 2016). The technique is also commonly used to estimate the role of marine resources in non-human food webs (e.g., Hobson and Welch 1992; Hoekstra et al. 2002; Quinn et al. 2012) and as a device for tracking migration patterns among an array of Arctic taxa including bowhead whale, anadromous fish and migratory waterfowl (e.g., Blight et al. 2015; Hobson and Wassenaar 2008; Kurle and Worthy 2001; Schell 1983; Schell et al. 1988).

3.1. Marine Stable carbon isotope chemistry

Carbon occurs naturally in two stable forms or isotopes. ^{12}C is the most common making up approximately 98.89% of global carbon; whereas ^{13}C , with an extra neutron, comprises approximately 1.11% of the earth's carbon. When atmospheric carbon (CO_2), dissolved CO_2 , or marine bicarbonates (HCO_3^-) are incorporated into plant tissues during photosynthesis, metabolic processes alter or fractionate the ratio of ^{13}C to ^{12}C depleting it relative to the substrate from which it was taken. This ratio is expressed in delta ($\delta^{13}C$) notation (Coplen 2011) as parts per mil (‰) difference from PDB (Pee Dee Belemnite), an internationally recognized standard (Craig 1957).

207 The degree of discrimination against $^{13}\text{CO}_2$ is a function of photosynthesis
 208 (Farguher et al. 1989). Lichens, cool season grasses, trees and most bushy plants employ
 209 C_3 photosynthetic mechanisms, discriminating heavily against ^{13}C , expressing a mean
 210 $\delta^{13}\text{C}$ value of $-26.7 \pm 2.7 \text{ ‰}$ (n=370) (Cerling et al. 1998). Plants grown before fossil fuel
 211 depletion of atmospheric CO_2 are enriched 1.5-2 ‰ relative to these averages (Marino
 212 and McElroy 1991; Tieszen and Fagre 1993). Similarly, Suess effect surface ocean
 213 depletion of $\delta^{13}\text{C}$ is $\sim -0.2 \text{ ‰}$ per decade since the extensive burning of fossil fuels
 214 (Bacastow et al. 1996; Gruber et al. 1999; Sonnerup et al. 1999).

215 Kinetic processes governing bicarbonate (HCO_3^-) formation in seawater
 216 fractionate marine bicarbonates approximately +7 ‰ relative to atmospheric CO_2 (-7 ‰),
 217 placing seawater $\delta^{13}\text{C}$ values near 0 ‰ (Tauber 1981; Chisholm et al. 1982). Submerged
 218 marine plants employ a C_3 photosynthetic pathway with its associated heavy
 219 discrimination against ^{13}C , yielding mean $\delta^{13}\text{C}$ values typically $\sim 7 \text{ ‰}$ more positive than
 220 terrestrial C_3 plants, giving them a distinctive marine label and placing bone collagen
 221 from individuals with diets high in marine foods in the -13 to -12 ‰ range (Coltrain
 222 2011; 2010a, b; 2009; Coltrain et al. 2004; Guiry et al. 2015; Laffoon et al. 2016).

223 $\delta^{13}\text{C}$ values in coastal, Arctic marine food webs are also influenced by other
 224 factors. Ocean upwelling recycles old carbon depleted in ^{13}C (Schell et al. 1988) and
 225 terrigenous carbon enters marine food webs at the deltas of large rivers drainages
 226 (Dunton et al., 2006; Naidu, et al., 2000; Raymond et al. 2007). For example,
 227 zooplankton from bowhead summer feeding grounds off the Mackenzie River delta
 228 produced $\delta^{13}\text{C}$ values 8 ‰ more negative than zooplankton collected in the Chukchi Sea,
 229 the whales' winter range (Schell et al. 1988; also see Peterson et al. 1986). However,

sections of baleen laid down during summer versus winter feeding episodes exhibit merely a 3 ‰ difference illustrating that the isotope chemistry of baleen is a weighted average of intraspecific variation in lower-order diets. The $\delta^{13}\text{C}$ values of Nuvuk foragers subsisting high in the marine food web represent a further averaging of intraspecific variation since the carbon in prey soft tissue is subject to continuous turnover unlike baleen, a keratinous protein metabolically inactive after formation.

$\delta^{13}\text{C}$ values are transferred up the food web leaving a diagnostic signature in the tissue of consumers that does not covary with the skeletal element analyzed or sex of the sample independent of gender differences in feeding ecology (Hobson and Schwarcz 1986; Lovell et al. 1986). Fractionation between primary producers and consumers approximates 5 ‰ and enrichment at higher trophic levels approaches 1 ‰ (Burton and Koch 1999; Katzenberg 1993). Adult bone collagen $\delta^{13}\text{C}$ values represent a weighted average of long-term diet since the carbon in adult bone collagen turns over slowly, requiring ca. 30 years to replace existing carbon with an equivalent amount of carbon (Harkness and Walton 1972; Hedges et al. 2007; Libby et al. 1964; Manolagas 2000; Stenhouse and Baxter 1979, 1977).

3.2. Nitrogen isotope chemistry

Nitrogen isotope ratios ($\delta^{15}\text{N}$) are measured against atmospheric air (AIR [Junk and Svec 1958]) and monitor the trophic level of sampled diets. This follows from the understanding that $^{15}\text{N}/^{14}\text{N}$ increases ~3-4.5 ‰ with each increase in trophic level enriching the isotope signature of nitrogen available for protein synthesis (Ambrose and DeNiro 1986; Schoeller 1999), although the mechanisms that result in enrichment are not fully understood. Most terrestrial plant taxa obtain nitrogen from soil ammonium (NH_4^+)

or nitrate (NO_3^-) and those in temperate ecosystems have mean $\delta^{15}\text{N}$ values of 3-6 ‰ with a 0-9 ‰ range, contingent upon temperature and water stress (Bocherens and Drucker 2003; Pate 1994). Accordingly, herbivores in such ecosystems typically exhibit $\delta^{15}\text{N}$ values of 6-9 ‰ (Ambrose 1991; Heaton et al. 1986; Schwarcz et al. 1999). Conversely, plants that fix atmospheric nitrogen (legumes, mosses and lichens) have mean $\delta^{15}\text{N}$ values of ~ 1 ‰, with a -2 to 2 ‰ range (Evans and Ehleringer 1994; Pate 1994), evidenced by depleted $\delta^{15}\text{N}$ values characteristic of barren ground caribou for whom lichens make up a significant component of their forage (Coltrain 2011; Coltrain et al. 2004). Phytoplankton, primary producers in marine ecosystems, exhibit nitrogen isotope ratios in the 4-8 ‰ range with a mean of ~6 ‰ (Fry 1988; Granger et al. 2004; Needoba et al. 2003).

3.3. Collagen extraction and radiocarbon dating

Whole bone samples weighing ~500 mg were cleaned of surface contaminants and demineralized in 0.6N HCl at 4°C. The supernatant was decanted and replaced daily until a density gradient was no longer visible. Type 2 pure water was used throughout in glassware baked out at 550° C. Demineralizing whole rather than crushed bone produces a collagen pseudomorph. This process allows preservation to be closely monitored and is complete when the supernatant is free of calcium phosphate, visible as a density gradient, and the sample is "spongy" when probed.

The pseudomorph was then rinsed to neutrality and soaked in 5% KOH, poured off and replaced daily until the supernatant was clear. This procedure removes soil organic contaminants such as humic and fulvic acids. After acid and base extraction, the collagen pseudomorph was rinsed to neutrality and gelatinized in 5 ml of water (pH 3) for

24 hrs. at 90°C. Water-soluble and -insoluble phases were separated with a 0.45µ Luer-Lok syringe filter and the water-soluble phase lyophilized and weighed to obtain a collagen yield.

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were determined relative to PDB and AIR, respectively, on acid and base extracted bone collagen. Flash combustion in a Carlo Erba Elemental Analyzer 118 CHN produced CO_2 and N_2 , which were then measured against the appropriate reference gas on a Finnigan Delta Plus mass spectrometer at the Stable Isotope Ratio Facility for Environmental Research (SIRFER) on the University of Utah campus. Stable carbon and nitrogen isotope measurements and weight percent C:N values were obtained with a single sample combustion. Analytical precision is ± 0.1 ‰ for carbon and ± 0.2 ‰ for nitrogen.

Radiocarbon dates were measured on purified bone collagen at the NSF Arizona AMS Facility. Two commonly used assays of preservation are reported in Table 1, weight percent collagen yield and atomic C:N ratios. Radiocarbon years before present were normalized with measured $\delta^{13}\text{C}$ values.

4. Results

4.1. Stable isotope values

Nuvuk burials (n=54) exhibit a mean $\delta^{13}\text{C}$ value of -14.1 ± 0.8 ‰ and $\delta^{15}\text{N}$ value of 20.5 ± 1.1 ‰ with a range of 3.3 ‰ and 5.2 ‰ respectively (Table 1). $\delta^{15}\text{N}$ values are positively correlated with $\delta^{13}\text{C}$ as expected in marine ecosystems since each increase in trophic level enriches both isotopes (Figure 2). However, $\delta^{13}\text{C}$ values account for merely half the variation in $\delta^{15}\text{N}$ illustrating the complexity of coastal marine food webs. Atomic C:N ratios are near modern with a mean value of 3.2 ± 0.1 ; collagen yields are also near

modern, averaging $20.8 \pm 4.6\%$ indicating excellent protein preservation given modern bone is ~25% collagen by weight (Ambrose 1990).

4.2. Gender and age patterning

Twenty-eight burials were sexed, although the sexing of one male and one female was questionable. The mean $\delta^{13}\text{C}$ value for female burials ($n=15$) is $-14.1 \pm 0.5\text{‰}$, virtually identical to the larger population; whereas the mean for males ($n=13$) is $-13.9 \pm 1.0\text{‰}$, not significantly different from that of females. The mean $\delta^{15}\text{N}$ value for female burials is $20.3 \pm 0.8\text{‰}$, again virtually identical to the larger population; whereas the mean for males is $20.6 \pm 1.3\text{‰}$, not significantly different from that of females. However, male diets are significantly more varied (carbon: $p=0.03$, $F=3.568$; nitrogen: $p=0.05$, $F=2.979$), exhibiting both standard deviations and ranges nearly twice that of females (Table 2).

Twenty-nine individuals in the study population were adults at the time of death, four were between the ages of 12-18, and seven were subadults under the age of 12, of whom only one was an infant. The remaining 14 burials were not aged. Sample sizes are small and no significant differences in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ exist between age categories. However not surprisingly, subadults express the most enriched mean $\delta^{15}\text{N}$ value ($21.0 \pm 1.2\text{‰}$) among the three age categories, since a subset of these individuals was likely either nursing or recently weaned (Coltrain and Janetski 2013; Katzenberg et al. 1996).

4.3. Calibration of AMS radiocarbon dates

AMS radiocarbon dates cover a two-sigma range of cal. A.D. 975-1885. Confidence interval median (CIM) dates range from A.D. 1139-1669 with a mean of A.D. 1308 ± 115 and median of A.D. 1276. Although uncalibrated dates in radiocarbon

years exhibit an average uncertainty of ± 37 , uncertainty in the marine reservoir correction ($\Delta R = 447 \pm 123$) significantly broadens the two-sigma range of calibrated dates. This ΔR correction is the error-weighted average of seven pre-bomb readings, four on Point Barrow and three on Chukchi Sea bivalves collected near Icy Cape (McNeely 2006). No Alaskan Beaufort Sea ΔR readings were available in the CALIB Marine Reservoir Correction Database (<http://intcal.qub.ac.uk/marine>). During calibration the ΔR correction was weighted by percent marine carbon in sampled diets. This value was calculated with estimated end member, bone collagen marine and terrestrial carbon $\delta^{13}\text{C}$ values of -12.0‰ and -20.0‰ respectively. The former is based on the most positive collagen $\delta^{13}\text{C}$ value in our data set (-12.4‰); the latter is the estimated collagen $\delta^{13}\text{C}$ value for an individual entirely reliant on terrestrial and/or freshwater prey (-20.0‰). This end member value derives from the mean $\delta^{13}\text{C}$ value (-24.2‰) of modern barren ground caribou and broad whitefish (*Coregonus nasus*) (Table 3), a freshwater fish found in local rivers discharging into Admiralty Bay. The isotope values of both modern taxa were measured on non-delipidified muscle tissue and were corrected $+4\text{‰}$ in accord with Suess effect ($+2$) and the offset between muscle tissue and bone collagen ($+2$) (Crowley et al. 2010:Table 1; Hobson and Clark 1992; Hobson et al. 1996; Logan et al. 2008). In the absence of direct isotope measurements on archaeofauna from the Barrow region, it was necessary to estimate end member values; an in depth discussion of paired dates on human remains and associated funerary materials is presented below and provides additional support for calibrated age ranges based on these estimates.

5. Discussion

5.1. Nuvuk diets

The lack of stable isotope data on Point Barrow archaeofauna precludes the use of a Bayesian mixing model such as SISUS (Erhardt et al. 2014) to reconstruct Nuvuk diets. Proxy faunal data are available but such data introduce additional uncertainty in mixing model outcomes. Jensen (2009a: Table5; 2009b:Table 1) published a limited set of carbon isotope readings on AMS dated faunal material from Nuvuk; however $\delta^{13}\text{C}$ values are on graphite, which can fractionate several per mil during graphitization and are thus not suitable for dietary reconstruction. For comparative purposes, stable isotope data on modern barren ground caribou, broad whitefish and a suite of marine taxa are shown in Table 3. Marine and freshwater data are on non-delipified muscle tissue from sea mammals and fishes taken in native subsistence hunts in the Barrow region (Dehn et al. 2006; Hoekstra et al. 2002; Lee et al. 2005). Caribou data are also on non-delipified muscle tissue taken during native culling of the caribou herd reintroduced to Southampton Island, Nunavut, Canada in 1967 (McLeman 2006). In the last column of Table 3, broad whitefish and caribou $\delta^{13}\text{C}$ values are adjusted + 2‰ to correct for fossil fuel depletion of atmospheric CO_2 (Marino and McElroy 1991; Tieszen and Fagre 1993); the same adjustment is applied to the $\delta^{13}\text{C}$ value of marine taxa, correcting for surface ocean depletion of marine bicarbonates (Bacastow et al., 1996; Gruber et al., 1999; Sonnerup 1999).

Given a Nuvuk mean $\delta^{15}\text{N}$ value of 20.5 ± 1.1 ‰ and median of 20.6 ‰ high trophic level marine mammals, primarily pinnipeds and toothed whales, appear to make up the bulk of intake. Bowhead whale and fishes are clearly in the diet but of less importance. Heavy reliance on ice-adapted seals ($\delta^{15}\text{N} = 16.9$ ‰) and beluga whale (*Delphinapterus leucas*) ($\delta^{15}\text{N} = 16.6$ ‰) accords well with ~4 ‰ fractionation between

diet and bone collagen characteristic of diets high in animal protein. In contrast, modern barren ground caribou express an average $\delta^{15}\text{N}$ value of 4.0 ± 0.2 ‰ (n=244) (McLeman 2006). Although, as noted, these data derive from a managed, eastern Arctic herd culled annually by native hunters, it is reasonable to assume that depleted $\delta^{15}\text{N}$ values are broadly representative of barren ground caribou elsewhere given their reliance on nitrogen-fixing tundra vegetation. A small set of archaeological samples (n=10), also from the eastern Arctic, produced an average $\delta^{15}\text{N}$ value of 2.8 ± 0.3 ‰ (Coltrain et al. 2004:Table 3). Taken together these data suggest that barren ground caribou made little contribution to Nuvuk diets.

Although whaling appears to define the Thule here and elsewhere (Coltrain et al. 2004; McCartney and Savelle 1985; Sabo and Jacobs 1980; Savelle et al. 2000), ice-adapted, ringed (*Phoca hispida*) and bearded seal (*Erignathus barbatus*) likely made a greater contribution to Nuvuk diets and the proximity of Elson Lagoon and other lagoon settings along the Beaufort Sea shelf may have increased intake of beluga whales. Jensen (2009a:103) notes that whereas fast moving beluga are difficult to take, they tend to feed in bays and estuaries during summer months and are hunted more successfully in shallow waters. Elson Lagoon also supports several fish taxa including Arctic char (*Salvelinus alpinus*) and all five species of Alaska salmon (*Oncorhynchus* spp.).

The recognition that sealing likely made the greatest contribution to Point Barrow Thule diets does not diminish the socio-culture role of whaling. Bowhead whales were the highest ranked resource among the suite of marine mammals exploited by Thule foragers. Bowheads were undoubtedly taken upon encounter at considerable risk and

their successful exploitation was tightly linked to perceptions of male identity and prestige.

5.2. Comparative data on high latitude marine foragers

To further examination Nuvuk diets, we plot Nuvuk bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values against those of other high latitude marine foragers (Figure 3), whose dietary reconstructions were based on isotope analysis of site-specific faunal assemblages. Results of a one-way ANOVA comparison of means are shown in Table 4. All sets of data are normally distributed (Shapiro-Wilk test) with the exception of Nuvuk $\delta^{13}\text{C}$. However, tests for skewness and kurtosis accept normality and Nuvuk mean and median $\delta^{13}\text{C}$ values differ by merely 0.02 ‰.

Kagamil (n=32) and Shiprock (n=16) mean isotope values represent 48 individuals from the eastern Aleutians broadly coeval with Nuvuk burials (Byers et al., 2011; Coltrain 2010b; Coltrain et al., 2006). Early in the twentieth century, these individuals were removed as mummified remains from burials caves on Shiprock and Kagamil islands (Hrdlička 1945). The mean Kagamil/Shiprock $\delta^{15}\text{N}$ value (-20.4 ± 0.7 ‰) is virtually identical to that of Nuvuk burials but Kagamil/Shiprock $\delta^{13}\text{C}$ values (-12.6 ± 0.4 ‰) are significantly enriched ($p < 0.001$) (Table 4) reflecting diets dominated by offshore pinnipeds and fishes (Byers et al.:Table 2). Umnak Island, Chaluka Midden inhumations (n=32) are also eastern Aleutian in origin (Laughlin and Marsh, 1951). With a few early exceptions, they are also coeval with Nuvuk burials (Coltrain et al. 2006:Table 1) but express slightly lower trophic level marine diets ($\delta^{13}\text{C} = -12.3 \pm 0.5$ ‰, $\delta^{15}\text{N} = 19.2 \pm 0.6$ ‰), distinguished by greater reliance on nearshore pinnipeds and fishes than either Nuvuk or Kagamil/Shiprock remains.

Kamarvik and Silumiut are Thule whaling villages on northeastern Hudson Bay again coeval with Nuvuk burials. Kamarvik/Silumiut ($n=111$) mean $\delta^{13}\text{C}$ ($-14.3 \pm 0.4 \text{ ‰}$) is not significantly different from that of the Nuvuk but $\delta^{15}\text{N}$ values ($17.4 \pm 1.4 \text{ ‰}$) are significantly depleted ($p < 0.001$) (Coltrain 2011; Coltrain 2009:Table 2; Coltrain et al. 2004). These diets are comprised of approximately 65% ringed seal, 20% bowhead whale and 15% caribou (Coltrain 2009:770), the latter depleting $\delta^{15}\text{N}$ relative to the Nuvuk. In contrast Sadlermiut, Native Point burials ($n=45$) recovered on Southampton Island across Roes Welcome Sound from the Thule whaling villages, are heavily reliant on ringed seal and sea birds with diets virtually devoid of caribou (Coltrain 2009:768). These burials date to the early twentieth century and express enriched $\delta^{13}\text{C}$ values ($-13.2 \pm 0.3 \text{ ‰}$), significantly more positive than the Nuvuk mean ($p = 0.001$), but a virtually identical $\delta^{15}\text{N}$ mean value ($20.6 \pm 0.7 \text{ ‰}$).

The relationship between Nuvuk stable isotope chemistry and that of other high latitude marine foragers was initially puzzling. Whereas, the mean Nuvuk $\delta^{15}\text{N}$ value is as positive as Kagamil/Shiprock and Sadlermiut remains, indicating near total reliance on high trophic level marine prey, Nuvuk $\delta^{13}\text{C}$ values are significantly depleted relative to these groups but similar to the mean $\delta^{13}\text{C}$ value of Kamarvik/Silumiut burials for whom barren ground caribou comprise ~15% of intake. Highly enriched Nuvuk $\delta^{15}\text{N}$ values ($20.5 \pm 1.1 \text{ ‰}$) indicate that caribou were virtually absent from Nuvuk diets, yet Nuvuk $\delta^{13}\text{C}$ values suggest otherwise (Figure 3).

5.3. Polar bear diets

To further characterize Nuvuk diets we compare Nuvuk isotope values to those of modern polar bear (*Ursus maritimus*) from three locations along the Alaskan Beaufort

Sea coast between Barrow and Demarcation Point. Bentzen et al. (2007:Table 1) report stable isotope values for polar bear sampled on landfast or pack ice during spring of 2003, 2004 (n=139). Bears were immobilized, some up to 80 km offshore, examined, tagged and blood samples taken. Packed red blood cells produced a mean $\delta^{13}\text{C}$ value of -18.8 ± 0.2 ‰ and $\delta^{15}\text{N}$ value of 19.7 ± 0.3 ‰. A linear mixing model was used to determine reliance on ringed seal, bearded seal and bowhead whale with taxon specific $\delta^{15}\text{N}$ fraction offsets of 3.2 ‰ for seals and 3.5 ‰ for bowhead whale (see also Hilderbrand et al. 1996). These data yielded mean estimates of 64% ringed seal, 18% bowhead (scavenged) and 18% bearded seal in 2003 polar bear diets with an increase in reliance on ringed seal and declines in intake of both bowhead and bearded seal in the 2004 sample. Nuvuk burials exhibit a mean $\delta^{15}\text{N}$ value even more positive (+0.8‰) than that of polar bear, enrichment, in this case, not attributable to the difference in sampled tissues since bone collagen and red blood cells express similar nitrogen fractionation offsets (Hilderbrand et al. 1996:Figure 4).

As apex predators, polar bear are a useful analog for the Nuvuk and further support our characterization of Nuvuk foragers as primarily reliant on high trophic level marine prey but do not explain depleted $\delta^{13}\text{C}$ values relative to other high latitude marine foragers. In fact, the same problem exists with Beaufort Sea polar bear carbon isotope chemistry. Despite being forced onto land during summer months, polar bear consume virtually no terrestrial resources unless closely associated with modern settlements (Ramsey and Hobson 1991). Yet when adjusted for Suess effect and fractionation, polar bear express a mean $\delta^{13}\text{C}$ value very similar to that of the Nuvuk suggesting that both

Nuvuk foragers and the bears are exploiting a similar suite of prey taxa subsisting in an unusual marine carbon isoscape.

5.4. Terrigenous carbon in marine food webs

A better understanding of depleted Nuvuk $\delta^{13}\text{C}$ values is provided by several recent studies that investigate the export of riverine, terrigenous carbon into Arctic marine food webs (Benner et al. 2004; Dunton et al. 2006; Lee et al. 2005; Naidu et al. 2000; Raymond et al. 2007). Opsahl et al. (1999) assessed the abundance of lignin in ultrafiltered Arctic water masses reporting high concentrations of riverine derived, terrigenous organic matter in the surface Arctic ocean and Parsons et al. (1989:261) refer to two Beaufort Sea food webs “based either on autotrophic marine diatoms or on organic material derived from the [Mackenzie] river.” This research was preceded by the work of Schell et al. (1998) who reported significantly depleted $\delta^{13}\text{C}$ values in copepods feeding in the east Alaskan Beaufort Sea relative to the Chukchi. Like patterning is reflected in bowhead whale baleen laid down in Beaufort Sea summer feeding grounds off the Mackenzie delta versus winter-feeding in Chukchi/Bering waters (Lee et al. 2005; Schell and Saupe 1993; Schell et al. 1989). Accordingly, cod (*Boreogadus saida*) collected in eastern Beaufort lagoons express $\delta^{13}\text{C}$ values ~3‰ depleted over those taken in coastal settings (Dunton et al. 2006:Figure 10), indicating intake of ~72% terrestrial carbon.

Dunton et al. (2006) report specifically on the impact of terrigenous carbon in the west Beaufort Sea ecosystem. The west Alaskan Beaufort Shelf, comprising the coastline from Point Barrow to Demarcation Bay, is characterized by numerous barrier islands and shallow lagoons fed by rivers discharging into the Beaufort Sea. Spring freshwater runoff laden with organic sediments typically occurs prior to the melting of landfast ice,

depositing large amounts of terrigenous carbon in lagoon basins and creating an estuarine-like, near-shore food web with carbon inputs deriving primarily from C₃ tundra angiosperms and taiga (Naidu et al. 2000:525). For example, Elson Lagoon and the Colville River are characterized by organic sediments with $\delta^{13}\text{C}$ values $< -26\text{‰}$, similar to that of the Mackenzie shelf (Naidu et al. 2000:Figure 3). The offshore food web is also impacted as plumes of freshwater spread beneath landfast ice prior to melting and ice-entrained terrigenous carbon is transported seaward off the coastal shelf.

These studies suggest that depleted $\delta^{13}\text{C}$ values characteristic of Nuvuk foragers is not due to partial reliance on terrestrial prey such as caribou but primarily reflect the presence of terrigenous carbon in estuarine and near shore Beaufort Sea food webs. This understanding is in keeping with Sheehan's (1995) argument regarding the development trade networks between coastal and inland foragers. Sheehan argued that the fall caribou hunt was compromised by the movement of whales from summer feeding grounds in the Beaufort Sea to their winter range in Chukchi/Bering waters. Opportunistic exploitation of migrating bowheads likely required constant readiness in conflict with the caribou hunt, which took Thule hunters inland. This conflict facilitated the development of trade networks between coastal and inland groups, exchanging sea mammal oils for caribou hide and antler. Although Jensen (2009b:Table 1) reports nine Nuvuk cemetery radiocarbon dates on caribou, in all but one case fur, hide or antler were dated. The single caribou skeletal element analyzed returned a conventional ^{14}C date of 160 ± 40 radiocarbon years (Beta-220981) calibrating to a confidence interval median of A.D. 1781 with a two sigma range of A.D. 1663-1950 and a 64.7% probability of falling between A.D. 1717-1890, clearly postdating burials under study.

We are not arguing that Nuvuk foragers never took caribou but that the early fall hunt was attenuated by whaling and relative sedentism that accompanied it resulting in diets, which were on average high in marine mammals and largely devoid of terrestrial prey. Further empirical support for Thule Nuvuk diets is however needed and will rely on the opportunity for stable isotope analysis of archaeofauna from the Barrow region.

5.5. Calibration of Nuvuk radiocarbon dates

Calibrating radiocarbon dates on marine mammals or burials with marine intake has been considered problematic for decades (e.g., Dyke and Savelle 2009; McGhee and Tuck 1976; Park 1994; Tuck and McGhee 1983). We approach calibration of a calendric, two-sigma age range as we have in previous publications (Coltrain 2011; 2010a, b; 2009; Coltrain et al. 2006, 2004), by applying a regional reservoir correction weighted by percent marine carbon in the diet of each individual under study (Table 1). Among Nuvuk burials, terrestrial carbon appears to derive primarily from the food webs of high trophic level marine mammals foraging along the Beaufort Sea shelf as discussed above and is evidenced by depleted $\delta^{13}\text{C}$ coupled with highly enriched $\delta^{15}\text{N}$ values. Whether bone collagen marine carbon is inversely correlated with reliance on freshwater/terrestrial prey or marine prey ingesting terrigenous carbon, the ΔR correction is similarly weighted. As noted in Section 4.3, seven ΔR values are available between Barrow and Icy Cape yielding a pooled mean ΔR value of 447 ± 123 yrs. Unfortunately ΔR estimates are not available for the coastal Beaufort Sea between Point Barrow and Amundsen Gulf.

Recognizing problems associated with the calibration of marine dates, Coulthard et al. (2010) and Furze et al. (2014) recently published new marine ΔR values for regions

from Amundsen Gulf eastward through Arctic Canada, the former based on pre-bomb, marine mollusks and the latter on bowhead and beluga whales. Mollusk calibrated ΔR for the northwestern Canadian Archipelago is 335 ± 85 yrs.; whereas Furze et al. (2014) report a bowhead ΔR value of 170 ± 95 yrs. and beluga whale ΔR of 240 ± 60 yrs., determined on both live-harvest and subfossil samples. Clearly these ΔR estimates are less than the Barrow/Icy Cape value, yet the latter ΔR value, appropriately weighted, produces valid results as discussed below. In contrast new estimates cited above are based on readings from within the Canadian Archipelago and sites eastward, basins with ocean circulation patterns markedly different from that of the Beaufort and Chukchi seas.

The calibration of Nuvuk burial dates is further complicated by a subset of burials with associated wood (n=25), whalebone (n=2) and caribou fur dates (n=4) (Jensen 2009a: 265-372; 2009b: Table 1). Although all dated materials were not closely associated with burials, dates have been published on wood from intact grave frames and caribou fur thought to represent mortuary clothing (Table 5). Thus if an applicable calibration algorithm is used, the two sigma range of bone collagen dates should overlap well-associated funerary age ranges. Meeting this expectation is improved by high uncertainty in the local ΔR correction (± 123 yrs.) but challenged by the recognition that all wood used to frame Nuvuk graves was acquired as driftwood. The latter problem is somewhat mitigated by a seemingly short transport time for driftwood arriving on the northwest Alaskan coast. Originating primarily in subarctic riparian forests along the Mackenzie or Kuskokwim and Yukon rivers, driftwood, buoyant less than two years unless ice rafted, is carried by swift coastal currents to Barrow shorelines (Alix 2009, 2005; Dyke and Savelle, 2000; Funder et al. 2009). Thus if driftwood was retrieved shortly after

stranding, transport times would have been too short to measurably bias radiocarbon dates, although when in short supply, wood may have been salvaged from abandoned structures and thus date appreciably older than associated human remains.

Table 5 lists the subset of analyzed burials (n=26) for which paired radiocarbon dates on funerary materials are available. Wood dates with higher than expected uncertainty are radiometric (Jensen 2009b:Table1). All dates on funerary materials presented in Table 5 were recalibrated in the Calib Radiocarbon Calibration Program, Version 7.0html (Stuiver et al. 2013) or OxCal 4.2 (Brock Ramsey 2009a); both programs use IntCal13 and Marine13 calibration curves (Reimer et al. 2013). Spatial relationships between funerary materials and burials are tabulated as recorded by the excavators. In some cases, driftwood grave frames were partially if not completely intact or scraps of fur within the grave suggest the individual was interred on caribou hide. In other cases wood frames were dislodged or the association of a burial with funerary material was not clear.

We make three simple observations in support of calibrated burial dates: 1) Caribou fur is on average 715.5 radiocarbon yrs. younger than bone collagen extracted from four well associated burials. These burials exhibit a mean of 77.5% marine carbon in their diets (Table 1). Based on these data, an individual with 100% marine carbon in his diet would date 922 years older than the caribou fur on which he was interred. The error-weighted, average ^{14}C age of modern, pre-bomb bivalves sampled at Point Barrow and Icy Cape is 914 radiocarbon years (McNeely et al. 2006). This relationship lends support to the algorithm used to estimate percent marine carbon in sampled diets. 2) Findings are further supported by similar confidence interval median dates for Burial

2254 and associated whalebone. In contrast the whalebone date associated with Burial 2253 is considerably older than the burial itself but this individual was “very fragmentary and highly disturbed” (Jensen 2009a:319) calling into question the association of cetacean bone with human remains. 3) Burial 2249, with a well-constructed frame on three sides of the grave, illustrates the biasing effect on burial CIM dates of marked uncertainty in the Barrow/Icy Cape ΔR correction. The lower calibrated two-sigma range of both the burial and wood framing the grave is A.D. 1037, yet the upper two-sigma range of the former is 170 years younger than the latter, resulting in a CIM date 64 years younger than the wood frame itself. Despite this problem, the average difference between bone collagen CIM dates and reasonably well-associated wood is 7.5 calendar years, in good accord with estimates of driftwood transport time discussed above (Table 5).

Figure 4 plots the calibrated two-sigma range of wood and paired bone collagen dates for all graves for which wood framing was intact. In five cases, calibrated wood CIM dates are slightly older than burial dates as might be expected for driftwood. In four cases the pattern is reversed. Nonetheless all driftwood/bone collagen paired dates overlap at two-sigma. Figure 5 plots paired dates on caribou fur and Figure 6 paired whalebone dates. The effects of uncertainty in ΔR are readily apparent. With the exception of whalebone, the two-sigma range of burial dates significantly exceeds that of wood and caribou fur. These findings do not invalidate our results but mitigate against pooling paired dates given the potential biasing effects of high ΔR uncertainty on the central tendency of such dates. Future recalibration of burial dates is contingent upon isotope analysis of archaeofaunas from the Barrow region and/or a suite of new ΔR

estimates from the Alaskan Beaufort shelf, either of which would warrant a reexamination of our results.

6. Conclusion

The Alaskan Thule period is thought to date from late in the first millennium A.D. Point Barrow bone collagen burial dates cover a two-sigma range of cal. A.D. 975-1885. CIM dates range from A.D. 1139-1669 with a mean of A.D. 1308 ± 115 and median of A.D. 1276. It is difficult to determine if current dates fully represent the occupation of Nuvuk as a whaling village or if earlier burials have been lost to erosion as suggested by the Nuvuk 01 burial (A.D. 810-1020). However, it is clear that this mortuary assemblage dates to the window of time during which Thule foragers moved east through the Canadian Archipelago to occupy sites along Hudson Bay and coastal Greenland. Individuals under study expressed highly enriched $\delta^{15}\text{N}$ values, similar to that of polar bear, indicating they were reliant on high trophic level marine mammals, primarily ice-adapted seals and beluga whales with less reliance on bowhead whale and fishes. Caribou made little if any contribution to these diets despite depleted $\delta^{13}\text{C}$ values, which we attribute primarily to terrigenous carbon entering the marine food web at riverine estuaries along the Alaskan Beaufort shelf. Caribou hide and antler found at Nuvuk were likely acquired through trade with interior groups in exchange for sea mammal oils. Finally, this study highlights the need for well-supported, local ΔR marine reservoir corrections when calibrating radiocarbon dates on marine derived carbon, as several previous studies have addressed.

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Table 1

Nuvuk bone collagen stable isotope values and calibrated AMS radiocarbon dates

ACRF No.	Field No.	Sex	Age	$\delta^{13}\text{C}\text{‰}$ PDB	$\delta^{15}\text{N}\text{‰}$ AIR	Wt% C	Wt% N	Atomic C:N	Wt % Collagen	% Marine in Diet	AMS Lab Number	^{14}C Yrs BP	Sigma	Cal 2 σ Range AD	CI Median Cal AD
2235	06-F75-PLKFE	F	12-15	-14.4	20.1	44.4	15.6	3.3	13.1	70.2	AA89599	1318	37	1112-1418	1267
2236	06-A111	F	20-30	-14.5	19.5	42.6	15.4	3.2	24.7	69.0	AA89600	1331	41	1059-1402	1245
2237	06-A184		10-12	-15.6	18.9	39.6	13.3	3.5	11.4	54.8	AA89601	1051	34	1272-1459	1364
2238	06-A185-XFZFS		adult	-14.8	19.7	43.3	15.6	3.2	23.4	65.4	AA89602	1401	34	1005-1299	1159
2239	06-A213-BPKPZ		6-12	-15.2	21.2	40.7	13.2	3.6	11.3	60.3	AA89603	823	33	1442-1705	1585
2240	06-A213-QLYXH		adult	-14.6	20.8	42.4	14.5	3.4	16.2	68.0	AA89604	1085	37	1290-1584	1424
2241	06-BB20	M	39-46	-12.6	21.5	44.8	16.2	3.2	18.4	92.6	AA89605	1586	41	975-1413	1189
2242	06-BB54	M?	39-63	-13.0	21.0	42.3	15.4	3.2	19.7	88.0	AA89606	1460	35	1055-1440	1269
2243	06-CC68-78	F	20-25	-14.9	20.1	43.5	14.9	3.4	20.4	63.8	AA89607	1328	35	1034-1330	1211
2244	06-C116-FIOYS		10-12	-15.2	20.9	44.9	16.2	3.2	27.2	59.9	AA89608	1380	35	1001-1280	1139
2245	07-054-22	F	adult	-14.8	19.4	44.1	16.1	3.2	27.3	65.0	AA89609	1292	43	1067-1403	1251
2246	07-A297-17/18		subadult	-14.0	20.8	45.2	16.0	3.3	18.5	74.9	AA89610	1081	39	1319-1657	1484
2247	07-A298-68	F	51-59	-14.3	20.2	44.4	15.7	3.3	18.9	71.5	AA89611	1354	40	1055-1403	1242
2248	07-A513-OPZW4	M	40-45	-15.7	17.7	44.0	16.0	3.2	21.6	53.5	AA89612	1326	35	1019-1274	1141
2249	07-B35-23	F	30-40	-14.0	20.7	41.5	15.0	3.2	26.7	74.9	AA89613	1407	41	1037-1395	1220
2250	07-C500-PMIXX			-15.0	19.3	42.6	15.2	3.3	25.4	63.1	AA89614	1092	40	1266-1519	1385
2251	07-C24-42/43	F	37 $\pm$ 7	-14.5	19.9	44.2	15.9	3.2	28.1	69.3	AA89615	1353	45	1046-1393	1227
2252	07--D45-10	F	25+	-14.1	19.2	42.3	15.2	3.3	27.7	74.3	AA89616	1311	35	1123-1450	1303
2253	07-DD56-MQVRR	M	adult	-15.0	19.3	42.2	15.0	3.3	23.1	62.2	AA89617	894	34	1414-1683	1547
2254	07-EE67-XXBQT	F	50-59	-13.9	21.2	42.5	15.3	3.2	25.3	76.3	AA89618	1398	49	1044-1411	1237
2255	07-FF36, QZRSP		adult	-14.2	20.2	45.2	16.4	3.2	21.4	72.8	AA89619	1463	35	981-1316	1157
2256	07-G92-15		12-15	-13.2	22.4	43.5	15.7	3.2	23.3	84.9	AA89620	1310	36	1171-1546	1367
2257	07-G94-9		adult	-13.8	21.1	43.0	15.6	3.2	23.9	76.9	AA89621	1239	43	1196-1530	1368
2258	07-G94-20			-14.1	20.6	42.7	15.3	3.3	28.3	73.6	AA89622	1130	44	1289-1626	1429
2259	07-HO	M	45-60	-14.5	20.9	43.4	15.5	3.3	23.3	68.6	AA89623	1299	35	1115-1423	1273
2260	07-H39-38		13-17	-15.1	19.2	43.5	15.7	3.2	21.9	61.6	AA89624	1390	34	1001-1283	1142
2261	07-JJ22-YUCXV	M	20-25	-13.6	22.0	42.9	15.4	3.2	26.0	80.3	AA89625	1397	46	1060-1432	1269
2262	07-LL28-WBGTR	M	18-20	-14.0	20.6	43.1	15.5	3.2	26.6	74.7	AA89626	1377	34	1056-1407	1246
2263	08-C32-108-VUNFJ	M	adult	-14.3	19.6	43.9	15.7	3.3	20.5	71.3	AA89627	963	41	1400-1708	1557
2264	08-A625-?		4-5	-14.2	21.0	42.3	15.0	3.3	22.8	73.1	AA89628	1295	34	1146-1452	1308
2265	08-E78			-13.7	20.7	41.3	14.9	3.2	22.1	78.9	AA89629	1282	34	1178-1502	1352
2266	09-EE55-111		10-12	-12.9	21.5	43.3	15.5	3.3	20.7	89.4	AA89630	1402	33	1104-1499	1328
2554	08-E87-KAMOR	F	40-50	-13.6	20.3	44.5	16.2	3.2	19.0	80.1	AA100197	1280	50	1165-1533	1360

ACRF No.	Field No.	Sex	Age	$\delta^{13}\text{C}\text{‰}$ PDB	$\delta^{15}\text{N}\text{‰}$ AIR	Wt% C	Wt% N	Atomic C:N	Wt % Collagen	% Marine in Diet	AMS Lab Number	^{14}C Yrs BP	Sigma	Cal 2 σ Range AD	CI Median Cal AD
2555	09-C63-228-RVSN6	F	60+	-13.3	21.0	42.1	15.3	3.2	20.4	84.0	14B/0719	1390	30	1090-1458	1303
2556	08-D15-THRYD	F	20+	-13.3	21.8	41.9	14.7	3.3	9.2	83.9	14B/0720	1110	20	1323-1699	1527
2557	09-B96-FIRSQ			-15.4	18.8	43.1	15.5	3.2	15.2	57.5	14B/0721	1190	20	1169-1412	1290
2558	11-38-JZHTL			-13.8	19.8	42.8	15.7	3.2	19.8	77.1	AA103365	1370	39	1069-1427	1270
2559	B11A-949-189			-14.5	18.8	44.6	16.4	3.2	15.7	68.5	AA103366	1171	39	1226-1495	1365
2560	B11A-949-38-FCYRR			-14.7	20.7	43.0	15.7	3.2	22.0	66.2	AA103367	803	38	1481-1885	1669
2561	B11A-994-OPXSR	M	45-60	-14.2	19.7	44.5	16.3	3.2	15.7	72.9	AA103368	1399	40	1036-1388	1213
2562	08-D61-QSTLY	M	45-55	-13.6	21.2	44.5	16.2	3.2	22.7	80.2	14B/0722	1390	30	1072-1432	1275
2563	08-I50-MDBYZ	F	40-50	-14.5	19.7	43.4	15.6	3.2	16.0	69.1	AA103369	1246	58	1146-1467	1319
2564	08-D99-7-NUVNO	F?	20+	-13.6	20.8	42.6	15.5	3.2	19.9	80.4	14B/0723	1310	20	1170-1486	1343
2565	08-K4-ZITFB		adult	-14.6	19.3	44.1	16.2	3.2	18.0	66.9	14B/0724	1290	20	1116-1418	1269
2566	08-D61-OCZPT			-13.1	21.9	44.3	16.2	3.2	24.5	85.8	14B/0725	1350	30	1153-1518	1346
2567	10-A928-BHASH		12-18	-14.5	18.4	34.3	12.4	3.2	20.2	69.3	AA103370	1300	39	1115-1428	1277
2568	10-C78-FTTZD			-12.7	21.3	42.2	15.5	3.2	22.7	91.4	AA103371	1484	52	104-1455	1271
2569	09-625-206-TXN9B			-13.9	21.3	39.6	13.6	3.4	17.2	75.9	14B/0726	1320	30	1126-1452	1306
2570	09-063-143/144-PXVGG	M		-13.1	21.9	42.8	15.4	3.3	13.4	85.7	14B/0727	1340	30	1161-1523	1352
2571	10-D75-34-MXRCL		infant	-13.8	22.9	43.6	15.9	3.2	24.3	78.0	14B/0728	1320	30	1146-1469	1321
2572	10-175-ZQNPO	M		-12.4	22.4	44.5	16.4	3.2	21.3	95.2	AA103372	1539	44	1028-1449	1249
2574	10-A927-EVARB	M		-14.6	19.6	43.9	16.0	3.2	18.1	67.1	AA103373	1347	39	1039-1338	1217
2575	B10-A918-WTIKR			-13.8	20.0	44.0	16.1	3.2	23.7	77.5	AA103374	1395	39	1054-1415	1250
2733	06-B113-HECCT	F	39-46	-13.7	21.2	38.2	13.9	3.2	16.7	78.8	AA103375	1493	40	981-1341	1172

Table 2

Nuvuk cemetery stable isotope values by gender and age

	n	$\delta^{13}\text{C} \text{ ‰}$	$\delta^{15}\text{N} \text{ ‰}$
Adult Males	13	-13.9 ± 1.0	20.6 ± 1.3
Adult Females	15	-14.1 ± 0.5	20.3 ± 0.8
All Adults, >17 yrs.	29	-14.1 ± 0.7	20.3 ± 0.9
Adolescents, 12-17 yrs.	4	-14.3 ± 0.8	20.0 ± 1.7
Children, <12 yrs..	7	-14.4 ± 1.0	21.0 ± 1.2

Table 3

Modern stable isotope values on marine taxa taken in native hunts at Point Barrow, AK, and barren ground caribou taken during native hunts on Southampton Island, Nunavut, Canada.

Taxon	CommonName	n	Modern $\delta^{15}\text{N} \text{ ‰}$	Modern $\delta^{13}\text{C} \text{ ‰}$	^a SuessEffect Corr $\delta^{13}\text{C} (+2\text{‰})$	^b Ref
<i>Phoca hispida</i>	ringed seal	82	16.9 ± 0.6	-18.5 ± 0.8	-16.5	1
<i>Erignathus barbatus</i>	bearded seal	55	16.8 ± 0.9	-17.1 ± 0.5	-15.1	1
<i>Odobenus rosmarus</i>	walrus	6	13.5 ± 1.0	-16.9 ± 0.2	-14.9	1
<i>Arctogadus glacialis</i>	arctic cod	24	15.5 ± 1.0	-20.9 ± 0.4	-18.9	1
<i>Eleginus gracilis</i>	saffron cod	1	14.2	-22.0	-20.0	1
<i>Ammodytes hexapterus</i>	arctic sand lance	1	14.6	-22.5	-20.5	1
<i>Osmerus mordax</i>	rainbow smelt	10	14.8 ± 1.0	-21.2 ± 0.8	-19.2	1
<i>Liopsetta lacialis</i>	arctic flounder	3	12.6 ± 0.0	-19.7 ± 0.1	-17.7	1,2
<i>Oncorhynchus keta</i>	chum salmon	3	11.8 ± 0.2	-20.8 ± 0.2	-18.8	2
<i>Oncorhynchus gorbuscha</i>	pink salmon	7	10.8 ± 0.6	-20.4 ± 0.2	-18.4	2
<i>Coregonus nasus</i>	broad whitefish	20	10.6 ± 1.1	-26.0 ± 1.6	-24.0	2
<i>Balaena mysticetus</i>	bowhead whale	72	13.1 ± 0.3	-20.5 ± 0.6	-18.5	2
<i>Balaena mysticetus</i>	bowhead whale	17	14.3 ± 0.8	-19.7 ± 0.5	-17.5	3
<i>Delphinapterus leucas</i>	beluga whale	22	16.6 ± 0.1	-18.7 ± 0.2	-16.7	2
<i>Rangifer tarandus</i>	barren grd caribou	244	4.0 ± 0.2	-22.3 ± 0.6	-20.3	4

^aBacastow et al. 1996; Gruber et al. 1999; Marino and McElroy 1991; Sonnerup et al. 1999; Tieszen and Fagre 1993.

^b1. Dehn, et al. 2007:Table 3; 2. Hoekstra et al. 2002:Table 1; 3. Lee et al. 2005:Table 5; 4. Mcleman 2006.

Table 4

ANOVA results: One-way analysis of variance using a Bonferroni test for differences between means

Point Barrow, Eastern Aleutians and Eastern Arctic Burial Sites			<i>p</i> value $\delta^{13}\text{C}$ ‰	<i>p</i> value $\delta^{15}\text{N}$ ‰
Chaluka Midden	vs	Kagamil/Shiprock	0.02	<0.001
Chaluka Midden	vs	Kamarvik/Silumiut	<0.001	<0.001
Chaluka Midden	vs	Nuvuk	<0.001	<0.001
Chaluka Midden	vs	Sadlermiut	<0.001	<0.001
Kagamil/Shiprock	vs	Kamarvik/Silumiut	<0.001	<0.001
Kagamil/Shiprock	vs	Nuvuk	<0.001	ns
Kagamil/Shiprock	vs	Sadlermiut	<0.001	ns
Kamarvik/Silumiut	vs	Nuvuk	ns	<0.001
Kamarvik/Silumiut	vs	Sadlermiut	<0.001	<0.001
Nuvuk	vs	Sadlermiut	<0.001	ns

Table 5

Nuvuk calibrated AMS radiocarbon dates paried with radicarbon dates on associated grave materials

ACRF No.	Burial Number + Structure/Feature ID	^a Material Dated	¹⁴ C Yrs BP	Sigma	Δ Coll-Grave ¹⁴ C Yrs BP	Cal 2 σ Range AD	CI Median Cal AD	^b Notes
2235	06F-75-12-PLKFE	wood	820	40		1154-1277	1218	Wood frame around burial
		collagen	1318	37	498	1112-1418	1267	
2236	06-A111-20	wood	870	40		1043-1254	1169	Parellel wood strips, may represent frame
		collagen	1331	41	461	1059-1402	1245	
2238	06-A185-2-XFZFS	wood	910	40		1031-1208	1112	Wood some distance from grave
		collagen	1401	34	491	1005-1299	1159	
2240	06-A213-90-QLYXH	wood	600	40		1294-1411	1348	No wood frame, very close to surface
		collagen	1085	37	485	1290-1584	1424	
2241	06-BB20-EYCBO	wood	930	40		1022-1189	1100	Well preserved wood N and S end of burial
		collagen	1586	41	656	975-1413	1189	
2242	06-BB54-80	caribou fur	870	60		1036-1259	1160	Burial resting on hide
		collagen	1460	35	590	1055-1440	1269	
2243	06-CC68-86	wood	740	40		1215-1301	1267	Partial wood frame
		collagen	1328	35		1034-1330	1211	
2244	06-C116-70-FIOYS	wood	740	40		1215-1301	1267	Wood from W side of remains
		collagen	1380	35	640	1001-1280	1139	
2245	07-054-22	wood	670	50		1265-1399	1321	Decaying log west of grave
		collagen	1292	43	698	1067-1403	1251	
2247	07-A298-36	wood	780	60		1151-1383	1235	Wood, whalebone frame, very near surface
	07-A298-39	wood	540	50		1300-1445	1392	
		collagen	1354	40	574/814	1055-1403	1242	
2248	07-A513-OPZW4	wood	880	40		1037-1225	1156	Decaying wood frame
	07-A513-16	wood	790	50		1154-1292	1233	
		collagen	1326	35	446	1019-1274	1141	
2249	07-B35-23	wood	880	40		1037-1225	1156	Wood framed grave
		collagen	1407	41	527	1037-1395	1220	
2251	07-C24-11	wood	800	50		1153-1287	1227	Wood framed grave
	07-C24-25	wood	530	40		1312-1444	1405	Wood separate from grave
		collagen	1353	45	553/823	1046-1393	1227	

ACRF No.	Burial Number + Structure/Feature ID	^a Material Dated	¹⁴ C Yrs BP	Sigma	Δ Coll-Grave ¹⁴ C Yrs BP	Cal 2 σ Range AD	CI Median Cal AD	^b Notes
2253	07-DD56-MQVRR	whalebone	1610	40		992-1443	1221	Very fragmentary remains, highly disturbed
		collagen	894	34	-716	1414-1683	1547	
2254	07-EE67-XXBQT	whalebone	1560	40		1030-1466	1266	Whalebone from grave
		collagen	1398	49	-162	1044-1411	1237	
2255	07-FF36, QZRSP	wood	710	50		1219-1392	1285	Wood may be from plank covering grave
		caribou fur	790	40		1169-1280	1238	Badly disturbed, fur from grave
		collagen	1463	35	753/673	981-1316	1157	
2259	07-HO-XLOFT	caribou fur	410	40		1427-1631	1478	Somewhat disturbed, interred on caribou fur
		collagen	1299	35	889	1115-1423	1273	
2260	07-H39-30	wood	790	40		1169-1280	1238	Wood from grave
		collagen	1390	34	600	1001-1283	1142	
2261	07-JJ22	wood	700	40		1248-1392	1289	Fairly complete with wood frame
		collagen	1397	46	697	1060-1432	1269	
2262	07-LL28-27	wood	850	60		1040-1270	1179	Wood from grave
		collagen	1377	34	527	1056-1407	1246	
2263	08-C32-108-VUNFJ	wood	970	40		996-1159	1087	Highly disturbed, no frame present,
		wood	800	40		1166-1277	1232	
		collagen	963	41	-7/163	1400-1708	1557	
2556	08-D15-THRYD	wood	620	40		1288-1405	1348	No wood frame
		collagen	1110	20	490	1323-1699	1527	
2562	08-D61-QSTLY	caribou fur	680	40		1263-1394	1305	Interred on caribou fur
		collagen	1390	30	710	1072-1432	1275	
2563	08-I50-MDBYZ	wood	960	40		1012-1164	1092	No frame, decaying wood near foot of grave
		collagen	1246	58	286	1146-1467	1319	
2564	08-D99-7-NUVNO	wood	750	40		1208-1298	1261	Poorly preserved wood frame
		collagen	1310	20	560	1170-1486	1343	
2733	06-B113-16-HECCT	wood	880	40		1037-1225	1156	Partial wood frame
		collagen	1493	40	613	981-1341	1172	

^aDates on associated grave materials reported in Jensen, A.M., 2009. Radiocarbon dates from recent excavations at Nuvuk, Point Barrow, Alaska, and their implications for Neoeskimo prehistory. In: Gronnow, B. (Ed.), On the Track of the Thule Culture from Bering Strait to East Greenland Proceedings of the SILA Conference "The Thule Culture—New Perspectives in Inuit Prehistory." National Museum of Denmark, Copenhagen, pp. 45-62.

^bNotes see Jensen, A.M., 2009. Nuvuk, Point Barrow, Alaska: The Thule Cemetery and Ipiutak Occupation. PhD Dissertation, Bryn Mawr College, Bryn Mawr.

Figure Captions:

Figure 1. Map of study area: 1-Point Hope, 2-Icy cape, 3-Point Barrow, 4-Demarcation Point, 5-Yukon River, 6-Kuskokwim River, 7-Mackenzie River

Figure 2. Nuvuk bone collagen $\delta^{15}\text{N}$ values plotted against $\delta^{13}\text{C}$ values with regression statistics.

Figure 3a. Mean $\delta^{15}\text{N}$ values plotted against $\delta^{13}\text{C}$ at one standard deviation for prehistoric marine foragers from the following Arctic sites: Nuvuk—Pt. Barrow, AK, (herein); Kagamil/Shiprock—eastern Aleutian burial caves, Chaluka Midden—Umnak Island, eastern Aleutians (Byers et al., 2011; Coltrain et al., 2006); Kamarvik/Silumiut—Thule whaling villages, NW Hudson Bay, Sadlermiut—Native Point, Southampton Island, NW Hudson Bay (Coltrain et al., 2004, 2009).

b. Individual $\delta^{15}\text{N}$ values plotted against $\delta^{13}\text{C}$ for burials analyzed from sites noted above.

Figure 4. Calibrated two sigma age ranges for Nuvuk burials listed by ACRF number paired with calibrated dates on wood frames in reasonable association with plotted burials. Confidence interval median (CIM) dates are indicated with a + sign. See Table 5 for radiocarbon ages in years BP, calibrated age ranges, CIM dates and the association of wood framing to burials as recorded by the excavator.

Figure 5. Calibrated two sigma age ranges for Nuvuk burials listed by ACRF number paired with calibrated dates on caribou fur thought to represent mortuary clothing. Confidence interval median (CIM) dates are indicated with a + sign. See Table 5 for radiocarbon ages in years BP, calibrated age ranges, CIM dates and the provenience of caribou fur relative to burials as recorded by the excavator.

Figure 6. Calibrated two sigma age ranges for Nuvuk burials listed by ACRF number paired with calibrated dates on whalebone framing two graves. Confidence interval median (CIM) dates are indicated with a + sign. See Table 5 for radiocarbon ages in years BP, calibrated age ranges, CIM dates and the association of whalebone to burials as recorded by the excavator. Note that burial ACRF-2253 was fragmentary and highly disturbed calling into question the association of this burial with dated whalebone.

Figure 1

Bathymetry

Sea Depth (Meters)

Figure 2

Figure 3

Figure 4

OxCal v4.2.4 Bronk Ramsey (2013) r.5

Figure 5

OxCal v4.2.4 Bronk Ramsey (2013) r.5

Figure 6