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Be careful what you ask for: Archaeozoological evidence of mid-Holocene climate change in the Bering Sea and implications for the origins of Arctic Thule

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Introduction

The last great migration of people into Arctic North America involved the Thule, a highly mobile group that spread rapidly from northern Alaska to the islands of the Canadian Arctic and northwest Greenland about 1000 years ago (Schledermann and McCullough 1980; McGhee 2005). Archaeological investigations in Siberia and Alaska have so far failed to identify where and when the most basic elements of Thule culture developed. The fact that Thule used whale skeletal elements as architectural material in the construction of their semi-subterranean houses has led many researchers to characterise them as primarily subsistence whalers (e.g. Schledermann 1976, 1979; Dawson 2001; Dyke and Savelle 2001; Le Mouël and Le Mouël 2002; Savelle and McCartney 2003). As a consequence, the search for Thule origins has become virtually synonymous with finding the earliest evidence of whaling in the Bering Strait (e.g. Birket-Smith 1947; Larsen and Rainey 1948; Giddings 1960; Mason 1998; Dumond 2000).

While it has been assumed the technical skills, social structure and material culture necessary for Arctic whaling must have ancient roots on the Siberian shores of Chukotka (Figure 1), in part because it is adjacent to the route taken by virtually all whales on their spring migration through the Bering Strait, there are very few archaeological sites in that region older than 2300 years BP and none of those contain convincing evidence of subsistence whaling (e.g. Giddings 1960; Dinesman and Savinetsky 2003). In fact, whaling seems to have arisen fully developed on Chukotka about 2300 BP (Mason 1998; Mason and Barber 2003), leaving unresolved the questions of why, where and when whaling technology and culture developed.

Thule hunted bowhead (*Balaena mysticetus*) almost exclusively, while their ancestors in the Bering Strait also hunted gray whale (*Eschrichtius robustus*): although both species migrate through the Bering Strait each summer to feed in Arctic waters, gray whales tend to head west into the Chukchi Sea, while most bowhead move east into the Beaufort and beyond (Braham *et al.* 1984; Moore *et al*. 2002; Braham 2003; Dinesman and Savinetsky 2003; Savelle and McCartney 2003; Moore and Laidre 2006). In the Bering Strait, the predictable availability of migrating whales is inextricably tied to the seasonal ebb and flow of sea ice. All migrating whales (including beluga, *Delphinapterus leucas*) must wait until the receding sea ice clears the strait in late spring. The timing of this event varies from year to year, at times dramatically so (Dixon 2003; Grebmeier *et al*. 2006).

During the so-called 'Medieval Climatic Optimum', which began just before the start of the Thule 'migration' period at c. 1000 BP, sea ice is known to have retreated much further north in summer than it does today, leaving many island passes of the Canadian Arctic Archipelago ice-free (Dyke and Savelle 2001). It appears that as more and more open water became available during the Medieval period, bowhead and beluga migrated as far northeast as they could every summer. Was this extended migration of whales into the central Arctic the primary motive for the Thule exodus from Alaska (e.g. Schledermann 1976; Schledermann and McCullough 1980), or did it merely facilitate a resettlement of Thule that began for other reasons? Robert McGhee (2005), who once believed the former, now suggests that early Thule were keen traders who knew the value of metal and headed directly from northern Alaska for the northwest coast of Greenland in search of meteoric iron that had been discovered by earlier (Dorset) inhabitants. However, for the purposes of this discussion, the reason Thule decided to move into the eastern Arctic is immaterial; at issue is where they learned the skills that enabled survival in such an environment.

I contend bowhead whales were merely one aspect of a sea ice-edge ecosystem to which Bering Sea maritime hunters had adapted during the exceptionally cold conditions of the preceding Neoglacial, and when retreating sea ice moved northeastwards with climatic amelioration in the later Medieval period, those who had by that time become uniquely 'Thule' were well positioned to follow. In other words, Thule were not adapted to a specific migratory resource (i.e. bowhead whales), but to a particularly mobile habitat (the southern edge of seasonal sea ice) – a habitat where seals, as well as whales, were plentiful and first made extensive contact with prehistoric maritime hunters of the southern Bering Sea during the Neoglacial period.

The Neoglacial was a period of cold climate that began in the mid-Holocene and lasted more than 2000 years, from about 4700 to 2500 yr BP (see Crockford and Frederick 2007). Arctic regions of the Northern Hemisphere were the most significantly impacted by the Neoglacial, although some effects were certainly felt further south. I contend the Neoglacial is key to this story of developing, interacting and migrating human cultures in the North American Arctic because it precipitated a significant southward extension and persistence of the sea-ice edge that redistributed ice-obligate pinnipeds and migrating whales for more than 2000 years. Evidence of that redistribution comes from analysis of marine-mammal remains recovered from a recently excavated site in the eastern Aleutians, occupied during the last 1000 years of the Neoglacial.

Here, I summarise a comprehensive analysis of mammal remains from the Amaknak Bridge site (UNL50) on Unalaska Island (Crockford *et al.* 2004), dated to the period c. 3500–2500 BP, and include a comparison with fauna from two adjacent sites that were occupied before and after (Davis 2001; Knecht and Davis 2001, 2003; Crockford and Frederick 2007). These analyses indicate that sea ice and its associated fauna must have been present as far south as the eastern

Aleutians until at least early summer at the height of the Neoglacial, and as a consequence, sea ice must have persisted in the Bering Strait until late summer/early fall.

Such an expansion and seasonal persistence of sea ice (even if it did not occur every year to the same degree) would have effectively prevented whales from making summer migrations through the Bering Strait into the Arctic as they have done for the past 2500 years. Lack of whales passing through the Bering Strait into the Arctic for the 2000 years before 2500 BP not only explains the limited time depth for whaling cultures in the Bering Strait, but the virtual lack of coastal archaeological sites in that region before 2500 BP (the so-called 'Old Whaling' culture deposits at Cape Krusenstern, on the north shore of Kotzebue Sound (Mason and Ludwig 1990; Dumond 2000), are the notable exception). It is apparent, however, that maritime hunters in the eastern Aleutians successfully adapted techniques used to procure temperate pinnipeds and small cetaceans and applied them to the ice-obligate seals and whales that Neoglacial ice brought to their doorstep. I contend, therefore, that Arctic whaling technology developed as a component of ice-edge hunting in the southern Bering Sea during the Neoglacial and was later transmitted north into the Bering Strait and east into the Canadian Arctic and Greenland.

Bering Sea and sea ice

The Bering Sea is an immense semi-contained extension of the Pacific Ocean, bound on the south by the Aleutian Islands and on the north by the Bering Strait, the Pacific passage to the Arctic Ocean (Figure 1). The shallow Bering Strait lies just below the Arctic Circle, at about the same latitude as the northern half of Iceland.

Sea ice (also known as 'pack ice') is a defining feature of the highly productive Bering Sea

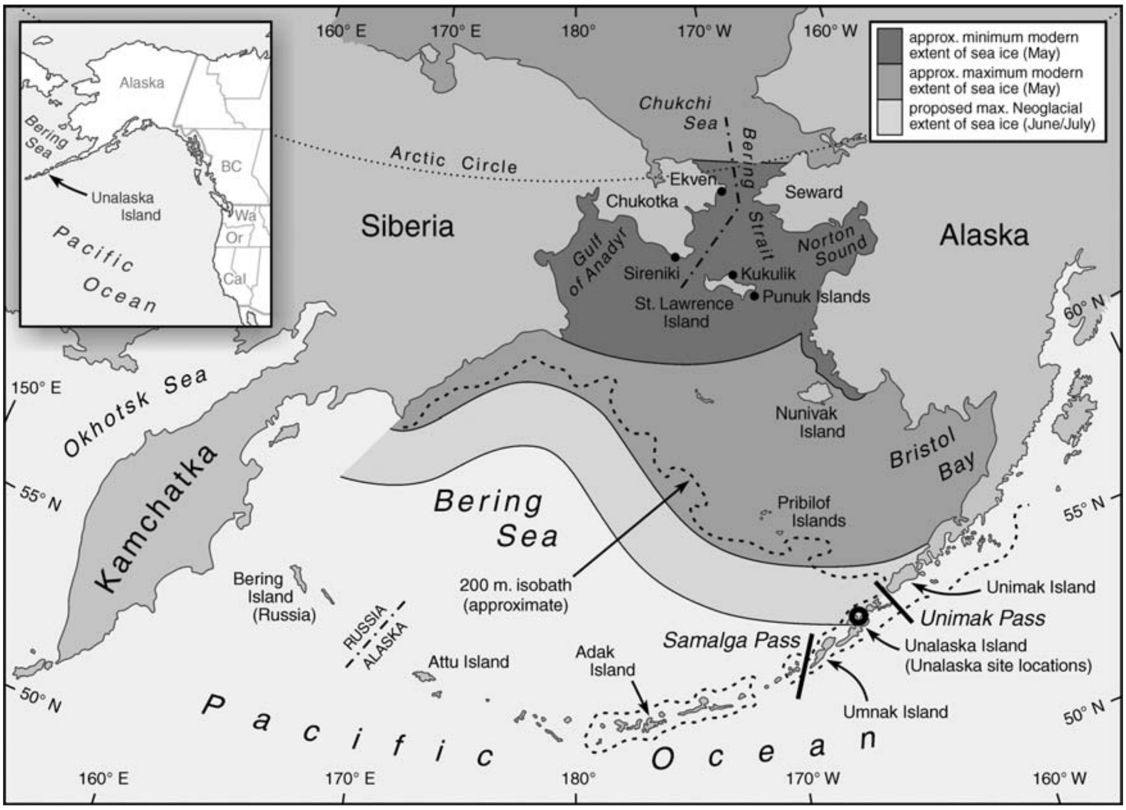

Figure 1. Modern minimum/maximum extent of spring pack ice (May) for the central and eastern Bering Sea, with proposed maximum Neoglacial pack ice extent (June/July). Archaeological sites mentioned in the text are labelled, with those on Unalaska circled (adapted from Crockford and Frederick 2007: Figure 1).

ecosystem (Grebmeier *et al*. 2006). Coverage of sea ice is governed primarily by wind, although air temperature has some bearing (Rigor and Wallace 2004). Sea ice forms over the Arctic continental shelf to the north in the early autumn (over the Chukchi and Beaufort Seas) and is pushed south by strong winds through the Bering Strait. Sea ice covers most of the shallow eastern portion of the Bering Sea by early winter, where it persists until spring and then recedes – at least, this has been the modern pattern.

Records show that historically, the leading edge of the sea ice usually reached its southernmost position by April or May, extending (on average) from the north end of Bristol Bay in the east (c. 58° N) to the Pribilof Islands at the shelf edge in the west, approximately following the 200 m contour line (Figure 1). While this line of maximum extent varies somewhat from year to year, the sea-ice edge generally recedes quickly by early summer (Grebmeier *et al*. 2006); in fact, during most of the 20th century, sea ice moved away from the Pribilofs by May and cleared the Bering Strait by June (Overland and Stabeno 2004).

The extent, persistence and movement of sea ice determines many aspects of life history for animals in the Bering Sea, especially marine mammals. While some whales, including humpback (*Megaptera movaeangliae*), North Pacific right whale (*Eubalaena japonica*), fin (*Balaenoptera physalus*) and gray whale, migrate in from the North Pacific in spring to feed in the Bering Sea over the summer and autumn, other cetaceans appear to be resident, including bowhead, beluga, Dall's porpoise (*Phocoenoides dalli*), harbour porpoise (*Phocoena phocoena*) and Baird's beaked whale (*Berardius bairdii*) (Moore *et al.* 2002; Reeves *et al.* 2002; Sheldon *et al.* 2005; Zerbini *et al.* 2006). Bowhead, gray whale and beluga move beyond the Bering Sea into the productive waters of the Beaufort and Chukchi Seas (Braham *et al*. 1984; O'Corry-Crow *et al.* 1997; Moore *et al*. 2000, 2002, 2003; Braham 2003; Dixon 2003). Arctic-adapted carnivores and pinnipeds that use sea ice as a substrate for mating, giving birth and nursing their young move with the ice as it ebbs north and south: these 'ice-obligate' or 'pagophilic' species include polar bear, *Ursus maritimus,* walrus, *Odobenus rosmarus,* bearded seal, *Erignathus barbatus,* ringed seal, *Phoca hispida*, spotted seal, *Phoca largha,* and ribbon seal, *Phoca fasciata* (Fedoseev 1975; Finley *et al.* 1983; O'Corry-Crow and Westlake 1997; Kelly 2001; Reeves *et al.* 2002; Simpkins *et al.* 2003). In contrast, 'temperate' Bering Sea pinnipeds prefer ice-free terrestrial beaches for these activities, including northern fur seal, *Callorhinus ursinus*, Steller's sea lion, *Eumatopias jubata,* and harbour seal, *Phoca vitulina* (Kenyon and Wilke 1953; Shaunghnessy and Fay 1977; Trites and Antonelis 1994; Ragen *et al.* 1995; Reeves *et al.* 2002).

Neoglacial marine mammal hunters in the Eastern Aleutians

Amaknak Bridge: Site location and archaeology

Unalaska is the second large island west of the Alaska Peninsula in the Aleutian chain (Figure 1). The region has been occupied by people for at least 9000 years (Knecht and Davis 2001). The Amaknak Bridge site (UNL50) is situated close to the major fishing port of Dutch Harbor on the Bering Sea side of the island, as shown in Figure 2. The archaeological deposits are classic shellfish middens with abundant well-preserved vertebrate fauna excavated from within and between seven recognisable house structures (Knecht and Davis 2004), dated c. 3500–2500 BP (selected ^{14}C dates: #862 – RCYBP 2590±90 BP, calibrated age BC 910–420, Beta-181341; #2909 – RCYBP 3000±70 BP, calibrated age BC 1410–1010, Beta-184634; #3152 – RCYBP 3470±70 BP, calibrated age BC 1950–1620, Beta-184633).

The semi-subterranean dwellings found at the Amaknak Bridge site are similar to those found at the nearby Margaret Bay site (dated c. 4700–4100 BP) and are basically rectangular in design, defined by rock walls about 1 m high. Uniquely styled fire-pit complexes are built into

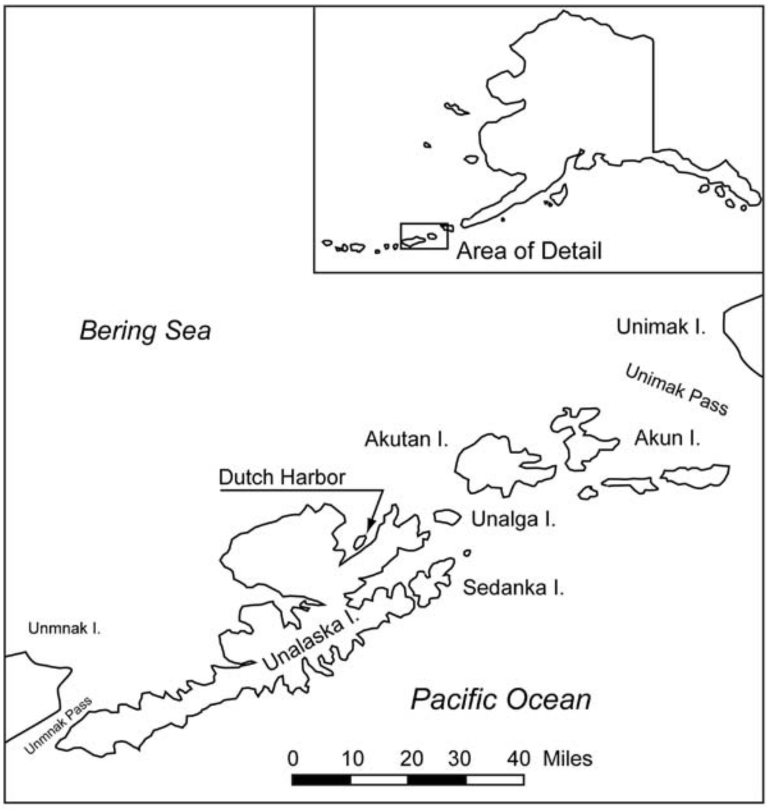

Figure 2. Location of the fishing port of Dutch Harbor on Unalaska Island, the general locale of the Amaknak Bridge site (UNL50), Margaret Bay (UNL48), and Amaknak Spit (UNL55), near the modern city of Unalaska. Note that Akutan Island (Stewart *et al.* 1987; Sheldon *et al.* 2005) hosted a shore-based whaling station in the early 20th century (processing mainly fin, humpback, sperm and blue whales but a few right whales), indicating many whales of these species were available within a short distance of the Amaknak Bridge site location (from Knecht and Davis 2004: Figure 1.02).

side walls: these fire pits have well-constructed chimneys extending above the rock wall and two rock-lined and rock-covered floor channels leading into the hearths in a converging V-shaped pattern. It now seems likely these unique floor channels were a necessary adaptation to the strong persistent north winds that must have characterised the Neoglacial, providing critical draft to the fire from below (cf. Knecht and Davis 2004). Similar draft arrangements are often prescribed today for maintaining an open fire under extremely windy conditions (Solid Fuel Association 2005).

Archaeozoological sample and analysis results

The total number of mammal specimens identified to species for the Amaknak Bridge assemblage is 5947, with 12,548 pieces identified to family level or better (Crockford *et al.* 2004). Age-at-death and sex determinations for all suitable pinniped specimens identified to species were based on comparison with modern specimens of known age and sex, as well as published references (Stora 2000). Basic quantification is by Number of Identified Specimens (NISP), the count of all specimens identified to species; however, NISP numbers designated as 'augmented' (as per Davis 2001) for comparison with other sites (Table 1) partition the undistinguished family NISP totals proportionally among the species identified.

Both resident and seasonally available temperate and pagophilic marine-mammal species are well represented at the Amaknak Bridge site: 40% northern fur seal (temperate, seasonal), 32% ringed seal (pagophilic, seasonal), 10% harbour porpoise (temperate, resident), 10% harbour and/or spotted seal (mixed temperate resident/pagophilic seasonal), 4% bearded seal (pagophilic, seasonal) and 3% Steller's sea lion (temperate, resident). All other taxa are present at a frequency of 1% or less, including Dall's porpoise, ribbon seal, walrus, polar bear, sea otter (*Enhydra lutris*), long-finned pilot whale (*Globicephala melaena*), beluga, fin whale, humpback, Baird's beaked whale, and North Pacific right whale. No dog remains were found.

Pagophilic species – ringed seal

Specimens of ringed seal, a species strongly associated with sea ice year round, comprise the second largest category of mammals recovered at Amaknak Bridge. Remains of newly weaned ringed seals (estimated at two-four months of age), which typically feed at the edge of sea ice (Wiig *et al.* 1999; Reeves *et al.* 2002), make up 90% of all ringed-seal remains for which an age could be estimated (Figure 3). Ringed seals in the Bering Sea, like bearded seals, move south with advancing sea ice in the spring, although their preferred habitat is generally towards the interior of the ice, where it is thick and unbroken (Kelly 2001; Simpkins *et al.* 2003). Ringed seals manage to continue feeding in this habitat because they maintain breathing holes in the ice. Ringed seals are born in March–May, with pups weaned at three to six weeks (Fedoseev 1975). Thus a pup born late in the season (around mid-May) might not be weaned until the end of June. Throughout the summer, newly weaned ringed seals feed close to the ice edge (Holst *et al.* 1999).

The very high proportion of young ringed seals represented at this site suggests that the sea-ice-edge habitat preferred by this age group must have been available close to the site location from early to mid-summer (May–July).

Pagophilic species – bearded seal

Analysis results reveal that although bearded-seal remains represent only 4% of the NISP, animals of all ages were harvested, including mature adults (17%) and newborns or newly weaned young less than two months of age (49%). Bearded seals haul out at the edges of consolidated sea ice or on large pieces of broken ice to give birth, nurse their young and moult (Reeves *et al.* 2002; Simpkins *et al.* 2003). Bearded seals move south in spring with advancing sea ice and north again as summer progresses. Birth of bearded seal pups occurs mid-March to early April (Reeves *et al.* 2002) and females wean their young after about 24 days. While newly weaned bearded seals feed at the ice edge, all other age classes (including adults, subadults and older juveniles) haul out on the ice for an extended moulting period that can last until August. As a consequence,

Table 1. Relative abundance and augmented NISP of pinniped species from Amaknak Bridge compared with adjacent sites in Unalaska Bay occupied before and after (pagophilic species in bold), adapted from Frederick and Crockford (2007).

Site	Ringed seal	Bearded seal	Steller's sea lion	Northern fur seal	Other seals	Site totals
Margaret Bay						
NISP	**604**	**0**	442	340	2653	5333
Percent	**11%**	**0**	8%	6%	50%	75%
Amaknak Bridge						
NISP	**4672**	**519**	389	4672	1298	12549
Percent	**36%**	**4%**	3%	36%	10%	89%
Amaknak Spit						
NISP	**0**	**0**	440	3534	314	4714
Percent	**0**	**0**	9%	75%	7%	91%

NISPs augmented as per Davis (2001), excluding whales. Age of the sites are: Margaret Bay (UNL48), c. 4700–4100 BP; Amaknak Bridge (UNL50), c. 3500–2500 BP; Amaknak Spit (UNL55), c. 600–350 BP. Taxa: Steller's sea lion, *Eumatopias jubata*; Northern fur seal, *Callorhinus ursinus*; Ringed seal, *Phoca hispida*; Bearded seal, *Erignathus barbatus*; 'Other seals' include *Phoca vitulina* and/or small amounts of *P. largha* and/or *P. fasciata*.

Figure 3. Juvenile ringed seal and bearded seal remains provide the strongest evidence that sea ice was present in spring/early summer adjacent to the Amaknak Bridge site, top to bottom panels. a) Amaknak Bridge bearded seal tibiae: far left, mature adult, proximal and distal ends (epiphyses completely fused, shaft missing); middle, estimated near-term foetus, complete (epiphyses poorly developed and unfused); far right, estimated 2–4 week old newborn, complete (epiphyses unfused); b) Amaknak Bridge bearded seal mandibles: top, young juvenile estimated 2–3 months old; bottom, mature adult; c) Tibiae of modern spotted seal vs. prehistoric and modern ringed seal: far left, University of Alaska Museum specimen #UA16605 spotted seal (ca. 3–4 weeks old); middle, Amaknak Bridge specimen #AB200152 ringed seal (estimated 2–4 months old); far right, University of Alaska Museum specimen #UA11581 ringed seal (ca. 6–8 weeks old).

both young pups and older animals are strongly associated with the sea-ice edge throughout the spring and summer, regardless of where the moving ice takes them.

If the timing of births for bearded seals was similar during the Neoglacial, pups two months old or less would have been available at the southern-most ice edge until the end of May. The strong representation of both adults and young pups (Figure 3) throughout the site assemblage suggests the preferred birthing and moulting haul-out habitat for bearded seals must have been very close to Unalaska Island at least through spring and early summer of most years (March–May) at the time the site was occupied.

Pagophilic species – walrus and others

Only six specimens of walrus were recovered from the area of the site covered by this report, representing at least four individuals (one adult male, one adult female, two juveniles). Walrus, being both larger and more gregarious in their hauling-out habits than bearded and ringed seals, require stronger, more consolidated pack ice. These particular ice conditions perhaps existed only rarely off the Amaknak Bridge site 3500 to 2500 years ago, since today in the northern

Bering Sea, walrus often occur in the same habitats as bearded and ringed seals (Kelly 2001; Simpkins *et al.* 2003). Alternatively, ice may have been present only over water too deep for effective walrus foraging.

The remains of other Arctic and pagophilic species, albeit recovered in low numbers, add to the picture of a cold, ice-dominated habitat at Amaknak Bridge: spotted seal (NISP=27), ribbon seal (NISP=6), beluga (NISP=1) and polar bear (NISP=8).

Cetaceans and evidence for whaling

All whale species identified to date have had the identifications confirmed by mitochondrial DNA (mtDNA) analysis (Frey *et al.* 2005). At least two individuals each of humpback, Baird's beaked whale, right whale and long-finned pilot whale have been identified so far, based on the distinct mtDNA haplotypes present; other whale species are represented by a single haplotype each. Surprisingly, each sequence recovered from the Amaknak whale remains represents a haplotype not found in modern animals tested so far.

The long-finned pilot whale remains represent a new record for this species off western North America. All previous records come from archaeological sites in Japan and as there is no evidence of an existing population, long-finned pilot whale is considered extinct in the North Pacific (Kasuya 1975; Reeves *et al.* 2002).

Interestingly, while Dall's porpoise appears to be the most common small cetacean noted in recent surveys of the southeast Bering Sea (e.g. Moore *et al.* 2002; Sinclair *et al.* 2005), harbour porpoise is not only strongly represented in the Amaknak Bridge assemblage, but comprises a surprisingly high proportion of the NISP (10%, 578/5947), with all age classes (including newborns and mature adults) represented. In contrast, although both gray whale and the smaller minke whale (*Balaenoptera acutorostrata*) are both fairly common during summer in the Bering Sea today (Moore *et al.* 2002; Sinclair *et al.* 2005; Zerbini *et al.* 2006), none have yet been positively identified from Neoglacial-age sites on Unalaska.

It is not surprising, however, that both right and fin whales are represented in the Amaknak Bridge assemblage, since the preferred summer habitat for both species in the Bering Sea is the shelf region just north of Unalaska (Stewart *et al.* 1987; Moore *et al.* 2002; Sheldon *et al.* 2005; Zerbini *et al.* 2006). Similarly, the preferred habitat for Baird's beaked whale (the largest of the beaked whale family, reaching 12.8 m) is the shelf slope (Stewart *et al.* 1987; Moore *et al.* 2002; Reeves *et al.* 2002); a portion of this habitat lies adjacent to Unalaska, suggesting this species may have been relatively common in the area prehistorically.

The assertion that Amaknak Bridge inhabitants deliberately hunted whales is supported not only by the presence of toggling harpoons and lances (Knecht and Davis 2004), but by the large number of whale elements found in the faunal midden that were not used for building purposes. While few very large pieces of architectural whale bone (including crania, mandibles and a few vertebrae) were included in the faunal assemblage presented for analysis, a sizeable number of relatively intact whale elements (including vertebrae) were nevertheless identified among the analysed faunal remains (Crockford *et al.* 2004). Of 40 pieces of whale bone from the analysed faunal subsample that could be assigned to body part (excluding rib and hyoid fragments, which were often indistinguishable), 14 (35%) were flipper elements, 15 (37.5%) were skull fragments and 11 (27.5%) were vertebrae (three of these vertebrae were near-terminal caudals); of an additional 30 whale elements identified from units not included in the analysed subsample, 15 (50%) were flipper elements, 7 (23%) were skull fragments, 7 (23%) were vertebrae (three were near-terminal caudals) and one (3%) was an intact sternum (Figure 4).

Savelle and McCartney (2003) consider whale flipper, sternum and hyoid elements found

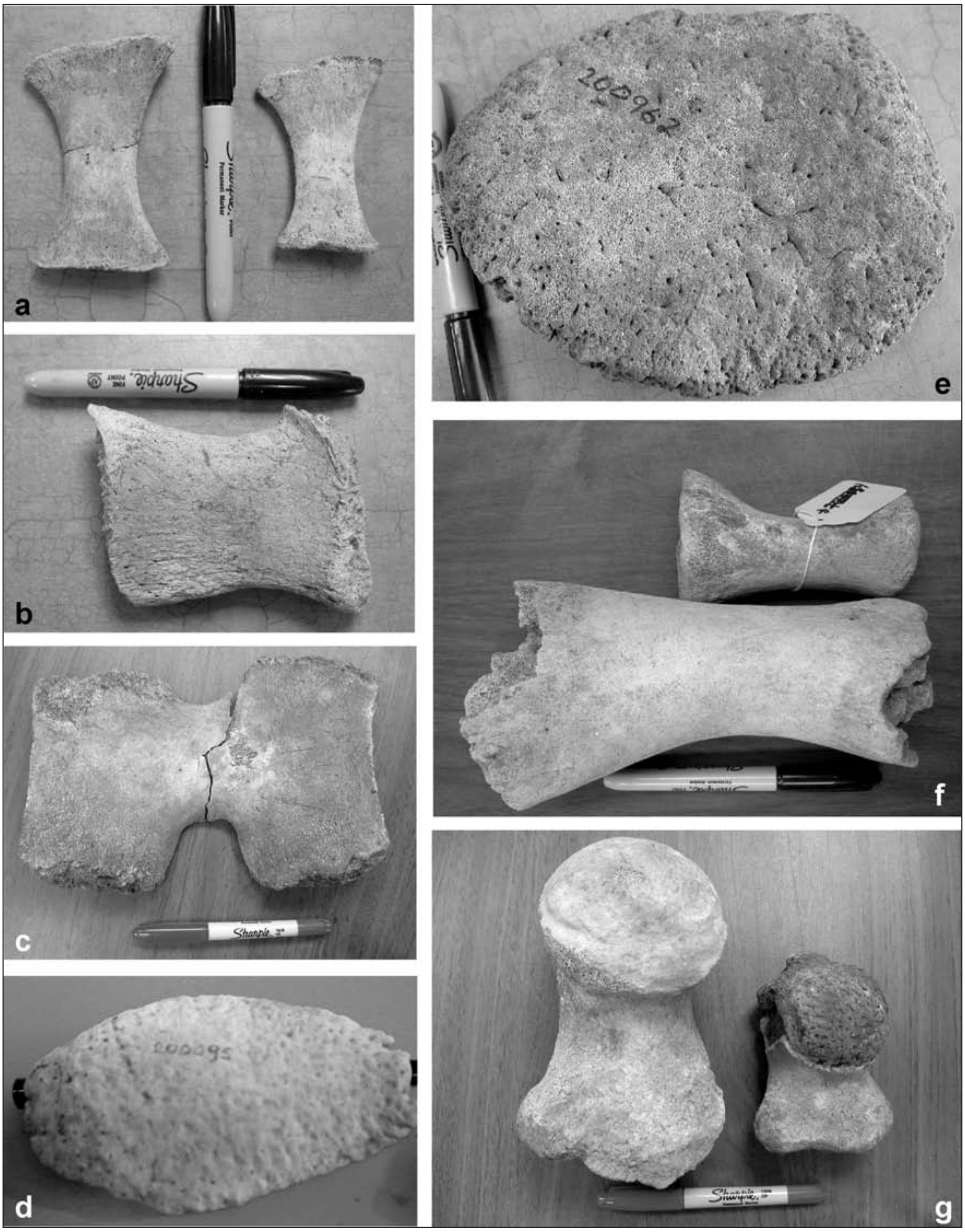

Figure 4. Much of the whale bone recovered from the Amaknak Bridge site represent body parts generally considered to represent food remains rather than architectural material and all species identifications have been confirmed by mtDNA analysis (Frey *et al.* 2005). Shown are: a) phalanges, humpback whale; b) metacarpal, fin whale; c) sternal plate, Baird's beaked whale; d) proximal epiphysis of radius, humpback whale; e) proximal epiphysis of radius, North Pacific right whale; f) phalanges, North Pacific right whale; g) humeri (adult, left; juvenile, right), long-finned pilot whale (first North American record of this species).

archaeologically to represent food items, and Jolles (2003) states that modern Bering Strait whalers distribute the flippers and tail stalk with flukes (presumably with the last few caudal vertebrae attached) to the boat captain of the whaling crew. Thus, while some whale bone was clearly used for architectural purposes, whales were evidently being consumed as food at Amaknak Bridge as well, and this implies active hunting.

Comparison with other assemblages

Two previously excavated sites with analysed faunal assemblages appropriate for comparison are located within 3 km of the Amaknak Bridge site: 1. Margaret Bay (UNL48), with fauna-bearing layers dated c. 4700–4100 BP, as well as deposits without fauna dated to c. 5500 BP (Davis 2001; Knecht and Davis 2001); 2. Amaknak Spit/Tanaxtaxak (UNL55), identified by David Yesner (University of Alaska) and dated to c. 600–350 BP (Knecht and Davis 2003). Comparison of dominant taxa at these sites (Table 1) shows that seasonally available pagophilic pinnipeds (ringed and bearded seal) are absent from post-Neoglacial-age deposits at Amaknak Spit and only weakly represented at the early Neoglacial-age site of Margaret Bay.

Archaeozoological analysis conclusions

Together, juvenile remains of the two pagophilic pinnipeds, ringed and bearded seal, provide incontrovertible evidence that at the height of the Neoglacial, spring sea ice reached a more southerly position than it does today, and persisted until summer. Increased polar winds in the Bering Sea (Rigor and Wallace 2004) must have forced sea ice, along with its associated pagophilic fauna, south to the eastern Aleutians by early April, where it persisted into June or July. Sea-ice coverage may not have reached the suggested extent every year during the Neoglacial, but much more extensive coverage than occurs at present must have been the predominant condition.

In addition, such an extent of sea ice and its persistence into summer indicates the Bering Strait must have been blocked with ice virtually year-round from c. 4700 BP to c. 2500 BP, preventing migration of whales into Arctic waters during the Neoglacial. Sea ice probably retreated north as summer advanced during the Neoglacial, as it does today, but it is unlikely that ice cleared the Bering Strait much before late summer or early autumn. With the Bering Strait ice-bound until late summer at the earliest, whales that currently use the Beaufort and Chukchi Seas for summer feeding, including bowhead, beluga and gray whales, must have either established resident populations in the Bering Sea or migrated elsewhere. The lack of subfossil (non-cultural) bowhead remains in the western Arctic and the virtual absence of archaeological sites with bowhead or gray-whale bone in the Bering Strait during this period support this conclusion (Dyke and Savelle 2001; Dixon 2003; Dyke and England 2003; Mason and Barber 2003; Savinetsky *et al*. 2004; Fisher *et al.* 2006). The oldest deposits at Cape Krusenstern on Kotzebue Sound, variously dated to c. 3200–2800 BP (e.g. Mason and Ludwig 1990) and termed 'Old Whaling,' appear to be the only real anomaly in this pattern. The Devil's Gorge site on Wrangel Island (also known as Chertov Ovrag), dated to c. 3100 BP, may be another (Dumond 2000). However, the evidence for subsistence whaling at Cape Krusenstern is not particularly strong.

Thule origins, ice-edge hunting and whaling

Due in part to a long tradition of characterising Thule as a whaling culture with a Bering Strait ancestry, determining Thule origins has become synonymous with finding the earliest northern Bering Sea sites with evidence of large-scale Arctic whaling. However, there are few archaeological sites in the Bering Strait older than 2300 BP, and none of these contain evidence of subsistence whaling (Mason and Barber 2003). Bering Strait sites with abundant bowhead remains are not at all common until after about 1300 BP, a few centuries before the emergence of Thule culture in Northern Alaska; virtually all sites in the 2300–1300 BP range are on the Siberian side of the Bering Strait (Chukotka) and contain primarily gray-whale remains (Dinesman and Savinetsky 2003; Savinetsky *et al.* 2004). Nevertheless, the oldest sites in the Bering Strait that have evidence of whaling are considered the first to show resemblance to Thule culture. Termed 'Old Bering Sea' and 'Birnirk', sites with many Thule-like material-culture elements appeared quite suddenly about 2300 BP and were widespread on both sides of the Bering Strait by c. 1500 BP (Mason 1998). A culture with even more Thule-like elements, 'Punuk', emerged about 1300 BP.

The similarities between Bering Strait cultures and Thule are quite apparent archaeologically and are summarised in Table 2. Thule, like their Bering Strait ancestors, were accomplished whalers, and this is reflected archaeologically by remains of skin boats, lances and large toggling harpoons, as well as by bowhead-whale skeletal remains left around their habitation sites; whales were not only consumed, but the bones were used for house construction. However, both Thule and their Bering Strait predecessors hunted walrus, as well as ringed and bearded seals, evidenced by the large accumulations of pinniped remains at their archaeological sites (e.g. Møhl 1979; Staab 1979; Morrison 1983; Gusev *et al.* 1999; Woollett *et al.* 2000; Savinetsky *et al.* 2004). For transport, skin boats were supplemented by Thule and some late Bering Strait predecessors (e.g. Kukulik on St Lawrence Island, Table 2) with sleds pulled by teams of dogs, reflected archaeologically by harness parts, line swivels and sled runners, as well as by the remains of dogs themselves (Morey and Aaris-Sørensen 2002). Thule took Beringian-style pottery lamps and pots with them on their initial eastward migrations, but appear to have used traditional stone lamps for heating and cooking, as their houses in the high Arctic had no hearths for open fires, in contrast to most Bering Strait dwellings. The environment in which all Arctic-adapted people lived demanded skin clothing with tightly sewn waterproof and windproof seams, reflected archaeologically by fine bone needles with very small, drilled eye holes – in rare cases in the high Arctic, the clothing itself has also been preserved. Thule prowess at carving walrus ivory, utilising small bits of iron acquired through trade, is legendary and unique, although ivory carving has a long tradition in the Bering Sea also.

Thule archaeological sites, as well as those of earlier Bering Sea people, thus contain these distinctive elements of their material culture: large toggling-type harpoons, lances, pottery, stone lamps, dog-harness components and sled parts, fine bone needles with very small eyes, elaborately carved ivory, and faunal assemblages containing the remains of dogs, bowhead whales, walrus, bearded seals and ringed seals.

In contrast, summarised as bold entries in Table 2, some Arctic Thule elements (especially small-eyed needles) are represented archaeologically in the eastern Aleutians by c. 4700 BP, at Margaret Bay. By c. 3500 BP, at Amaknak Bridge, quite a few Thule-like artefacts are found, including toggling harpoons, stone lamps, labrets, carved ivory and small-eyed needles, in addition to the remains of whales and other ice-edge marine mammals. I propose, therefore, that the most essential element of Thule culture, sea ice-edge hunting technology (including the boats and clothing required to hunt in such habitats), has its most ancient roots in the eastern Aleutians during the Neoglacial.

In contrast, a few researchers (e.g. Clark 1966, 1996; Dumond and Bland 1995; McGhee 2005) have looked to the Gulf of Alaska (particularly Kodiak Island) for the origins of Thule culture. There, by c. 3500 BP, there are stone lamps, ground slate tools and small-eyed needles. Collins (1937) and others, such as Giddings (1960), have noted especially strong similarities between Thule material culture and that of late-prehistoric inhabitants of St Lawrence Island (referred to as 'Punuk' culture, one example being the site of Kukulik, listed in Table 2). Mason and Barber (2003:72) have suggested that, ultimately, 'whaling arose during the last centuries BC on the south shore of the Chukotka Peninsula, from Ekven to Sirenki, during a cooler interval', but note that sites on Chukotka with evidence of whaling appear suddenly and fully developed about 2300 BP, without local antecedents. Dumond (2006) has revised his earlier opinion on this issue, especially in light of the finds from Margaret Bay, and now deems an eastern Aleutian origin for essential Thule cultural elements to be the most parsimonious explanation.

I suggest that ice-edge hunting technology developed in the eastern Aleutians as strong north winds during the early Neoglacial occasionally drove spring sea ice as far south as Unalaska and kept it there until early summer (see Margaret Bay items in Table 1). Well-developed maritime hunting and fishing strategies were already in place at this time. From the abundance of porpoise remains at Margaret Bay (Davis 2001), for example, we can confidently infer that boats of some kind must have been in use by at least 4700 BP. While sea-mammal hunting was directed primarily towards temperate species in the early decades of the Neoglacial (especially harbour seals and sea lions), a few pagophilic species were also taken (primarily ringed seal, but

Table 2. Eastern Aleutian and Bering Strait sites versus early Thule site comparion (see Figure 1 for locations).

Location	**Eastern Aleutians**		**Kotzebue, AK**	**St. Lawrence Island**		**E. Greenland and Alaska**
Material culture	**Margaret Bay 5500–3000 BP**	**Amaknak Bridge 3500–2500 BP**	**Choris c. 2600 BP**	**Okvik ?2300 BP**	**Kukulik 1300–1100 BP**	**Early Thule* c. 1000 BP**
Toggling harpoons and lances	no	**yes**	no	**yes**	**yes**	**yes**
Stone lamps	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
Ground slate tools	few	no	few	yes	yes	yes
Labrets	**yes**	**yes**	**yes**	**yes?**	**yes**	**yes**
Fine needles	**yes**	**yes**	**yes**	**yes**	**yes?**	**yes**
Pottery	no	no	yes	yes	yes	yes
Iron	no	no	no	no	yes	yes
Open hearth	**yes**	**yes**	**yes**	**yes?**	**yes?**	**no**
Dog harness parts	no	no	no	no	yes	yes
Ivory carvings	no	**yes**	**?**	**yes**	**yes**	**yes**
Fauna						
Dogs	no	no	no?	yes	yes	yes
Large whales	few	**yes**	**yes**	**yes**	**yes**	**yes**
Ringed seals	**yes**	**yes**	**yes**	**yes?**	**yes**	**yes**
Bearded seals	no	**yes**	**yes**	**yes?**	**yes**	**yes**
Walrus	few	**yes**	no	**yes**	**yes**	**yes**

Table references: Geist and Rainey 1936; Rainey 1941; Larsen and Rainey 1948; Giddings 1960; Schledermann 1976, 1979; Møhl 1979; Staab 1979; Schledermann and McCullough 1980; Mason 1998; Woollett *et al.* 2000; Davis 2001; Knecht *et al.* 2001, 2004; Crockford *et al.* 2004; McGhee 2005.

* these early Thule cultural components are a composite of several.

some walrus and polar bear), although these may only have been available in years of particularly severe ice cover.

At the height of the Neoglacial – with sea ice pressing down from the north virtually every spring – very large numbers of ringed seal were available for hunting at the edge of the ice, as were bearded seals and the occasional walrus (as reflected by the faunal component at Amaknak Bridge in Table 1). Extensive sea ice to the east of Unalaska (along the Bristol Bay coast of the Alaska Peninsula and Unimak Island, Figure 1) would have blocked one of the main passages into the Bering Sea used by modern cetaceans (Moore *et al.* 2002; Ladd *et al.* 2005; Sheldon *et al.* 2005; Sinclair *et al.* 2005; Zerbini *et al.* 2006), forcing them to enter the Bering Sea west of Unalaska, where an eastward migration route would take all animals directly past the site location.

Today, spring migrating whales in the northern portion of the Bering Sea travel in the narrow strip of open water that lies between the shore and wind-driven sea ice, where they are far easier to hunt than autumn whales in relatively ice-free open water: modern Bering Strait whalers still find that spring whaling is the most successful (Bogoslovskaya 2003; Braham 2003; Jolles 2003). Along this moving edge of offshore sea ice, relatively large numbers of seals are also available during the spring and early summer (Nelson 1969).

Successful hunting in seasonal sea-ice-edge habitats not only would have demanded that prehistoric hunters amass detailed knowledge of how spring ice behaves (e.g. Nelson 1969; Oozeva *et al.* 2004), but also would have required the development of strategies for dispatching and butchering enormous animals with minimal manpower. Ethnographic information suggests that small group size probably did not preclude taking very large whales: early in the 20th century, for example, small groups of Bering Strait hunters were known to secure large whales to the ice edge and butcher them in the water (cutting off manageable chunks only, which would almost certainly include flippers), rather than hauling them on to land or ice, as is usual today (Carol Jolles pers comm. 2004). Harpooning seals that are in the water, when the hunter must work from a boat or the edge of sea ice, must have required quite different tactics from those used to hunt seals and sea lions on terrestrial haul outs, or even ringed seals from breathing holes (e.g. Pelly 2001). Of course, none of the above could have taken place without the invention and diligent construction of windproof and waterproof clothing; the ability to sew tight seams demanded careful butchering of carcasses to produce the essential skin and gut segments for such clothing (e.g. Wigen and Lam 2006), as well as very small needles and fine sewing line.

I agree with Morrison (1983) and others (e.g. Staab 1979; Henshaw 2003) who have suggested that early Thule and their immediate Bering Strait ancestors practised ice-edge hunting of ringed seals, rather than breathing-hole hunting. However, I contend that whales were almost certainly hunted in this habitat also (not in 'open water', as is often asserted, which implies lack of constraint by sea ice) and that this spring ice-edge hunting strategy was developed during the Neoglacial by remote ancestors of the Thule who lived far to the south. This ice-edge habitat became available in the Eastern Aleutians only during the late spring/early summer and was not so much an 'adapt or perish' situation, but an 'adapt for success' one: it is clear that plenty of temperate resources had been available for millennia at this location, but ice-edge resources must have added considerably to overall success, if only for the extra oil from such a surplus of marine mammals.

Once Neoglacial conditions ameliorated, however, people who chose to maintain the lifestyle of ice-edge hunting would have had to move north with the receding ice – or perhaps all were forced out by competing groups re-invading from the south. Regardless, virtually the first stop on such a journey northwards would have been St Lawrence Island, which lies smack in the middle of the Bering Strait and is now surrounded by sea ice about eight months of the year (Figure 1). Therefore, the archaeological record of St Lawrence Island has great significance to this story.

St Lawrence Island and the origins of Thule

St Lawrence Island lies just south of, and perpendicular to, the Bering Strait. It is a massive barrier that catches, along its full length, the brunt of wind-driven ice, whether the wind comes from the north or the south (Figure 1). While it is only about 65 km from the Siberian coast to the western end of St Lawrence, it is more than 160 km from Alaska in the east. Cultural ties on St Lawrence, today as in the past, are with Siberia; the Alaskan coast is beyond the range of traditional skin boats, which must be taken out of the water after a few hours or they sink (Rainey 1941; Giddings 1960). Many archaeological sites line the shoreline of St Lawrence, but few have been systematically excavated and many have been destroyed by looters (Mason 1998).

One of the best-known archaeological sites on St Lawrence Island is Kukulik, on the north shore. Kukulik dates to c. 1300–1100 BP and has a material culture known as 'Punuk' (Geist and Rainey 1936). Punuk-culture sites contain evidence of dog-drawn sleds, pottery, elaborately carved ivory, small-eyed needles and the toggling harpoons characteristic of whaling (Table 2).

What appears to be the oldest site in this region (Okvik) is on one of the Punuk Islands off the eastern end of St Lawrence, from which the later culture draws its name. Although the initial occupation date of c. 2300 BP has been contested (e.g. Mason 1998), there seems little doubt that these distinctive early deposits underlay those of true Punuk type and have some typical Old Bering Sea elements (Rainey 1941; Giddings 1960). Okvik contains virtually all elements of Thule material culture, including small-eyed needles and pottery, except dog-drawn sleds (Table 2). There are dog remains, but no sled or harness parts.

Aboriginal whalers thus seem to have arrived on St Lawrence Island with a fully developed Arctic-adapted culture, although admittedly the record is far from complete or well dated. However, no sites with similar elements that predate these deposits have been found so far on the Siberian coast (Mason 1998; Dumond 2000; Mason and Barber 2003; Savinetsky *et al.* 2004). Therefore, unravelling the origin of both Thule culture and Arctic whaling may hinge on determining where the initial colonisers of St Lawrence Island called home. I contend Punuk Islanders probably came initially from the south, along with retreating spring sea ice at the end of the Neoglacial. Thule and their immediate ancestors were thus not exclusively whaling specialists, but highly skilled sea ice-edge hunters, who harvested all species within that ecological zone, including bowhead whales, beluga, ringed and bearded seals, and walrus.

Key elements that continue from Amaknak Bridge through St Lawrence Island sites include evidence of whaling (both toggling harpoons and whale remains), evidence of ice-edge hunting (walrus, bearded seal and ringed seal remains), ivory carvings, small-eyed needles and stone lamps. New elements that appear on St Lawrence Island and elsewhere in the Bering Strait region about 1300 BP are indicative of an active Siberian trade network with Korea and China (Mason 1998). These Siberian elements include: 1. dogs and the technology for dog traction, such as harness buckles and line toggles (Morey and Aaris-Sørensen 2002); 2. smelted iron for arming lances, harpoon heads, arrows and carving tools (Mason 1998; McGhee 2005); 3. clay and associated skills for making fired pottery.

This integration of Siberian culture items is part of what made Thule so unique and successful: they were not only proficient at living in their sea-ice-edge habitat, they were also uniquely mobile. From early spring through mid-summer, dog-drawn sleds could have hauled boats and gear across expanses of moving or stationary sea ice (not just snow-covered land), while boats could have transported dogs, sleds and people between ice flows – a habitat where food was plentiful and easily available. Although travel during the winter would have been virtually impossible in the High Arctic because of constant darkness, dogs and boats could have been used together in spring/early summer to travel rapidly over quite large distances, especially if the receding spring ice was used as a moving platform. In other words, the Thule migration east need not have been confined to shorelines, but almost certainly was seasonally constrained.

Conclusions

I have argued that Thule were not adapted to a specific migratory resource (i.e. bowhead whales), but to the particularly mobile habitat that was the southern edge of sea ice, and that Thule ancestors learned how to hunt the various pinniped and cetacean species of this new habitat during the Neoglacial period, c. 4700–2500 BP, when that sea-ice habitat became a regular seasonal component of life in the eastern Aleutians.

Comprehensive analysis of the marine-mammal fauna from the Amaknak Bridge site documents the presence of seasonal sea ice and its associated fauna as far south as the eastern Aleutians and its persistence until at least early summer on a regular basis during the last half of the Neoglacial. Expansion and persistence of sea ice in the south must have been associated with a persistence of sea ice in the Bering Strait until late summer/early autumn, which would have prevented whales making early summer migrations through the Bering Strait into the Arctic, as they do today. Indeed, the presence of thick, virtually omnipresent sea ice over the northern half of the shallow Bering Shelf during the Neoglacial would have made all coastlines bordering the Bering Strait and Chukchi Sea virtually uninhabitable for whales as well as people, from the Gulf of Anadyr in the west, to the mouth of the Yukon River in the east, including St Lawrence Island.

I maintain that human adaptation to the dramatic increase in sea ice in the eastern Aleutians during the Neoglacial explains the sudden appearance of Arctic whaling in the Bering Strait just afterward, and ultimately, the origins of Thule culture. The most essential element of Thule culture, ice-edge hunting technology (including the boats and clothing required to hunt in that habitat), has its most ancient roots in the eastern Aleutians during the Neoglacial. I suggest that the earliest inhabitants of St Lawrence Island, including Punuk Islanders, probably came initially from the south along with retreating spring sea ice at the end of the Neoglacial, and over time, contact with Siberian cultures to the west introduced the remaining items of Thule culture: dog traction, smelted iron and pottery. Dog-drawn sleds, in combination with skin boats, made Thule people uniquely mobile, allowing them to travel rapidly over large distances.

Acknowledgements

I thank the Museum of the Aleutians (Unalaska) and local Aleut Corporation members for permission to study their collections, a project funded through the State of Alaska Department of Transport. Ole Haggen produced the map presented here and Pacific ID colleague Gay Frederick assisted with bone identification of Amaknak Bridge marine mammals. Managers and curators of the following institutions kindly made their skeletal collections available: Department of Anthropology, University of Victoria, Canada; Smithsonian Institution, Washington, DC; University of Alaska Museum, Fairbanks; Burke Museum, Seattle, WA. Robert McGhee, Don Dumond and Owen Mason provided useful commentary during discussions at the 2008 meeting of the Alaska Anthropology Association in Anchorage.

References

Birket-Smith, K. 1947. Recent achievements in Eskimo research. *Journal of the Royal Anthopological Institute of Great Britain and Ireland* 77:145–157.

Bodenhorn, B. 2003. Fall whaling in Barrow, Alaska: A consideration of strategic decision-making In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 277–306. Edmonton: Canadian Circumpolar Institute Press.

Bogoslovskaya, L.S. 2003. The bowhead whale off Chukotka: integration of scientific and traditional knowledge, In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 209–254. Edmonton: Canadian Circumpolar Institute Press.

Braham, H. W. 2003. Ancient whaling the biogeography of bowhead and gray whales, In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 185–207. Edmonton: Canadian Circumpolar Institute Press.

Braham, H.W., B.D Krogman and G.M. Carroll 1984. *Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, 1975–78*. NOAA Technical Report NMFS SSRF-778.

Clark, D.W. 1966. Perspectives in the prehistory of Kodiak Island, Alaska. *American Antiquity* 31:358–371.

Clark, D.W. 1996. The old Kiavak site, Kodiak Island, Alaska, and the early Kachemak phase. *Arctic* 49:211–227.

Collins, H.B. Jr., 1937. Cultural migrations and contacts in the Bering Sea region. *American Anthropologist* 39:375–384.

Crockford, S. and G. Frederick 2007. Sea ice expansion in the Bering Sea during the Neoglacial: evidence from archaeozoology. *The Holocene*17:699–706.

Crockford, S., G. Frederick, R. Wigen and I. McKechnie 2004. Final Report on the analysis of the vertebrate fauna from Amaknak Bridge, Unalaska, AK, UNL050. Report on file, Museum of the Aleutians, Unalaska, AK. [Supplement to *Amaknak Bridge Site Data Recovery Project Final Report,* Knecht, R. and Davis, R. 2004]

Davis, B.L. 2001. Sea mammal hunting and the neoglacial: An archaeological study of environmental change and subsistence technology at Margaret Bay, Unalaska. *University of Oregon Anthropological Papers* 58:71–85.

Dawson, P.C. 2001. Interpreting variability in Thule Inuit architecture: a case study from the Canadian High Arctic. *American Antiquity* 66:453–470.

Dinesman, L.G. and A.B. Savinetsky 2003. Secular dynamics of the prehistoric catch and population size of baleen whales off the Chukchi Peninsula, Siberia. In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 137–166. Edmonton: Canadian Circumpolar Institute Press.

Dixon, J.C. 2003. Environment and environmental change in the western Arctic and Subarctic: implications for whaling. In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 1–24. Edmonton: Canadian Circumpolar Institute Press.

Dumond, D.E. 2000. A Southern Origin for Norton Culture? *Anthropological Papers of the University of Alaska* 25:87–102.

Dumond, D.E. 2006. A Backward Glance from Alaska. In D.E. Dumond and R.L. Bland (eds), Archaeology in Northeast Asia: On the Pathway to Bering Strait. *University of Oregon Anthropological Papers* 65:207–226.

Dumond, D.E. and R.L. Bland 1995. Holocene prehistory of the northernmost North Pacific. *Journal of World Prehistory* 9:401–451.

Dyke, A.S. and J.M. Savelle 2001. Holocene history of the Bering Sea bowhead whale (*Balaena mysticetus*) in its Beaufort Sea summer grounds off southwestern Victoria Island, western Canadian Arctic. *Quaternary Research* 55:371–379.

Dyke, A.S. and J.England 2003. Canada's most northerly postglacial bowhead whales (*Balaena* *mysticetus*): Holocene sea-ice conditions and polynya development. *Arctic* 56:14–20.

Fedoseev, G.A. 1975. Ecotypes of the ringed seal (*Pusa hispida* Schreber, 1777) and their reproductive capabilities. In K. Ronald and A.W. Mansfield (eds), *Biology of the Seal*, pp. 156–160. Rapports et Proces-verbaux des Reunions, Conseil International Pour L'Exploration de la Mer.

Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski 1983. A distinctive large breeding population of ringed seal (*Phoca hispida*) inhabiting the Baffin Bay pack ice. *Arctic* 36:162–173.

Fisher, D., A. Dyke, R. Koerner, J. Bourgeois, C. Kinnard, C. Zdanowicz, A. de Vernal, C. Hillaire-Marcel, J. Savelle and A. Rochon 2006. Natural variability of arctic sea ice over the Holocene. *EOS (Transactions of the American Geophysical Union)* 87:273–280.

Frey, A., S.J. Crockford, M. Meyer and G. O'Corry-Crowe 2005. Genetic analysis of prehistoric marine mammal bones from an ancient Aleut village in the southeastern Bering Sea. *Abstracts of 16th Biennial Conference on the Biology of Marine Mammals,* p. 98. San Diego.

Geist, O.W. and F.G. Rainey 1936, *Archaeological excavations at Kukulik, St. Lawrence Island, Alaska.* Miscellaneous Vol. II. Washington, DC: Publications of the University of Alaska.

Giddings, J.L. 1960. The archaeology of Bering Strait. *Current Anthropology* 1:121–138.

Grebmeier, J., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W.Cooper, K.E. Frey, J.H. Helle, F.A.McLaughlin and S.L. McNutt 2006. A major ecosystem shift in the northern Bering Sea. *Science* 311:1461–1464.

Gusev, S. V., A.V.Zagoroulko and A.V. Porotov 1999. Sea mammal hunters of Chukotka, Bering Strait: Recent archaeological results and problems. *World Archaeology* 30:354–369.

Henshaw, A. 2003. Polynyas and ice edge habitats in cultural context: Archaeological perspectives from southeast Baffin Island. *Arctic* 56:1–13.

Holst, M., I. Stirling and W. Calvert 1999. Age structure and reproductive rates of ringed seals (*Phoca hispida*) on the northwest coast of Hudson Bay in 1991 and 1992. *Marine Mammal Science* 15:1357–1364.

Jolles, C.Z. 2003. When whaling folks celebrate: A comparison of tradition and experience in two Bering Sea whaling communities. In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 307–339. Edmonton: Canadian Circumpolar Institute Press.

Kasuya, T. 1975. Past occurrence of *Globicephala melaena* in the western North Pacific. *Scientific Reports of the Whales Research Institute* 27:95–110.

Kelly, B.P. 2001. Climate change and ice breeding pinnipeds. In G.R.Walther, A.B. Conradin and P.J. Edwards (eds.), *Fingerprints of Climate Change,* pp. 43–55. New York: Plenum.

Kenyon, K.W. and F. Wilke 1953. Migration of the Northern fur seal, *Callorhinus ursinus*. *Journal of Mammalogy* 34:86–98.

Knecht, R.A. and R.S. Davis 2001. A prehistoric sequence for the Eastern Aleutians. *University of Oregon Anthropological Papers* 58:269–288.

Knecht, R. and R. Davis 2004. *Amaknak Bridge Site Data Recovery Project Final Report* #MGS-STP-BR-0310(S)/52930. On file, Museum of the Aleutians, Unalaska and Alaska Department of Transportation, Anchorage.

Knecht, R. and R. Davis 2003. *Archaeological evaluation of Tanaxtaxak, the Amaknak Spit site (UNL-055) final report*. Unpublished report, Museum of the Aleutians, Unalaska.

Ladd, C., G.L. Hunt Jr., C.W Mordy, S.A Salo and P.J. Stabeno 2005. Marine environment of the eastern and central Aleutian Islands. *Fisheries Oceanography* 14(1):22–38.

Larsen, H. and F.G. Rainey 1948. Ipiutak and the Arctic whale hunting culture. *Anthropological Papers of the American Museum of Natural History* 42.

Le Mouël, J.F. and M. Le Mouël 2002. Aspects of early Thule culture as seen in the architecture of a site on Victoria Island, Amundsen Gulf area. *Arctic* 55:167–189.

McGhee, R. (ed) 2005. *The Last Imaginary Place: A Human History of the Arctic World.* Chicago: University of Chicago Press.

Mason, O.K. 1998. The contest between the Ipiutak, Old Bering Sea, and Birnirk polities and the origin of whaling during the first millennium A.D. along the Bering Strait. *Journal of Anthroplogical Archaeology* 17:240–325.

Mason, O.K. and V. Barber 2003. A paleo-geographic preface to the origins of whaling: cold is better. In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, pp. 69–107. Edmonton Canadian Circumpolar Institute Press.

Mason, O.K. and S.L. Ludwig 1990. Resurrecting beach ridge archaeology: parallel depositional records from St. Lawrence Island and Cape Krusenstern, western Alaska. *Geoarchaeology* 5:349–373.

Møhl, J. 1979. Description and analysis of the bone material from Nugarsuk: An Eskimo settlement representative of the Thule culture in west Greenland. In A.P. McCartney (ed), *Thule Eskimo Culture: An Anthropological Retrospective*, pp. 380–394. National Museum of Man, Mercury Series, Archaeology Survey of Canada 88.

Moore, S.E., D.P. DeMaster and P.K. Dayton 2000. Cetacean habitat selection in the Alaskan Arctic during summer and autumn. *Arctic* 53:432–447.

Moore, S.E., J.M. Grebmeier and J.R.Davies 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. *Canadian Journal of Zoology* 81:734–742.

Moore, S.E. and K.L. Laidre 2006. Trends in sea ice cover within habitats used by bowhead whales in the western arctic. *Ecological Applications* 16:932–944.

Moore, S.E., J.M. Waite, N.A. Friday and T. Honkalehto 2002. Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domain. *Progress in Oceanography* 55:249–261.

Morey, D.F. and K. Aaris-Sørensen 2002. Paleoeskimo dogs of the eastern Arctic. *Arctic* 55:44–56.

Morrison, D.A. 1983. *Thule culture in western Coronation Gulf, N.W.T.* National Museum of Man, Mercury Series, Archaeological Survey of Canada (Ottawa) 116.

Nelson, R.K. 1969. *Hunters of the Northern Ice.* Chicago: University of Chicago Press.

O'Corry-Crowe, G.M., R.S. Suydam, A. Rosenberg, K.J. Frost and A.E. Dizon 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. *Molecular Ecology* 6:955–970.

O'Corry-Crow, G.M. and R.L. Westlake 1997. Molecular investigations of spotted seals (*Phoca largha*) and harbor seals (*P. vitulina*), and their relationship in areas of sympatry. In A.E. Dizon, S.J. Chivers and W. F. Perrin (eds), Molecular Genetics of Marine Mammals. Special Publication Number 3, pp. 291–304. Lawrence: The Society for Marine Mammalogy.

Oozeva, C., C. Noongwook, G. Noongwook, C. Alowa and I. Krupnik 2004. *Watching Ice and Weather Our Way.* Washington DC: Arctic Studies Center, Smithsonian Institution.

Pelly, D.F. 2001. *Sacred Hunt: A Portrait of the Relationship Between Seals and Inuit*. Seattle, University of Washington Press.

Overland, J.E. and P.J. Stabeno 2004. Is the climate of the Bering Sea warming and affecting the ecosystem? *EOS (Transactions of the American Geophysical Union)* 85:309–316.

Ragen, T.J., G.A. Antonelis and M. Kiyota 1995. Early migration of northern fur seal pups from St.Paul Island, Alaska. *Journal of Mammalogy* 76:1137–1148.

Rainey, F.G. 1941. Eskimo prehistory: the Okvik site on the Punuk Islands. *Anthropological Papers of the American Museum of Natural History* 37(IV):455–569.

Reeves, R.R, B.S. Stewart, P.J. Clapham and J.A. Powell 2002. *National Audobon Society's Guide to Marine Mammals of the World.* New York: Alfred A. Knopf.

Rigor, I.G. and J.M Wallace 2004. Variations in the age of Arctic sea ice and summer sea ice extent. *Geophysical Research Letters* 31:L09401.

Savelle, J.M. and A.P. McCartney 2003. Prehistoric bowhead whaling in the Bering Strait and Chukchi Sea regions of Alaska: A zooarchaeological assessment. In A.P. McCartney (ed), *Indigenous Ways to the Present: Native Whaling in the Western Arctic,* pp. 167–184. Edmonton: Canadian Circumpolar Institute Press.

Savinetsky, A.B., N.K. Kiseleva and B.F. Khassanov 2004. Dynamics of sea mammal and bird populations of the Bering Sea region over the last several millennia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 209:335–352.

Schledermann, P. 1976. The effects of climatic/ecological changes on the style of Thule culture winter dwellings. *Arctic and Alpine Research* 8:37–47.

Schledermann, P. 1979. The "baleen period" of the Arctic whale hunting tradition. In A.P. McCartney (ed), *Thule Eskimo Culture: An Anthropological Retrospective,* pp. 134–148. National Museum of Man, Mercury Series, Archaeology Survey of Canada Paper No. 88.

Schledermann, P. and K. McCullough 1980. Western elements in the early Thule culture of the eastern high Arctic. *Arctic* 33:833–841.

Shaunghnessy, P.D. and F.H. Fay 1977. A review of the taxonomy and nomenclature of North Pacific harbour seals. *Journal of Zoology (London)* 182:385–419.

Sheldon, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade and D.J. Rugh 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. *Mammal Review* 35:129–155.

Simpkins, M.A., L.M. Hiruki-Raring, G. Sheffield, J.M Grebmeier and J.L. Bengtson 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. *Polar Biology* 26:577–586.

Sinclair, E.H., S.E. Moore, N.A. Friday, T.K. Zeppelin and J.M. Waite 2005. Do patterns of Steller sea lion (*Eumetopias jubatus*) diet, population trend and cetacean occurrence reflect oceanographic domains from the Alaska Peninsula to the central Aleutian Islands? *Fisheries Oceanography* 14(1):223–242.

Solid Fuel Association. 2005. *Curing chimney problems.* Solid Fuel Association, Derbyshire, UK, viewed 12 November 2007. http://www.solidfuel.co.uk/frame/main.html

Staab, M.L. 1979. Analysis of faunal material recovered from a Thule Eskimo site on the island of Silumiut, N.W.T., Canada. In A.P. McCartney (ed), *Thule Eskimo Culture: An Anthropological Retrospective*, pp. 349–379. National Museum of Man, Mercury Series, Archaeology Survey of Canada Paper No. 88.

Stewart, B.S., S.A. Karl, P.K. Yochem, S. Leatherwood and J.L. Laake 1987. Aerial surveys for cetaceans in the former Akutan, Alaska, whaling grounds. *Arctic:* 40:33–42.

Stora, J. 2000. Skeletal development in the grey seal *Halichoerus grypus,* the ringed seal *Phoca hispida botnica,* the harbour seal *Phoca vitulina vitulina,* and the harp seal *Phoca groenlandica:*epiphyseal fusion and life history. *Archaeozoologia,* XI:199–222.

Trites, A. W. and G.A. Antonelis 1994. The influence of climatic seasonality on the life cycle of the Pribilof Northern fur seal. *Marine Mammal Science* 10:311–324.

Wiig, O., A.E. Derocher and S.E. Belikov 1999. Ringed seal (*Phoca hispida*) breeding in the drifting pack ice of the Barents Sea. *Marine Mammal Science* 15:595–598.

Wigen, R. J. and Y. Lam 2006. Tool manufacturing and skinning marks on bird bones from the Amaknak Bridge site, Aleutian Islands, Alaska. Paper presented at the 10th meeting of the International Council for Archaeozoology, Mexico City, 23–28 August 2006.

Woollett, J. M., A.S. Henshaw and C.P. Wake 2000. Palaeoecological implications of archaeological seal bone assemblages: Case studies from Labrador and Baffin Island. *Arctic* 53:395–413.

Zerbini, A. N., J.M. Waite, J.L. Laake and P.R.Wade 2006. Abundance, trends and distribution of baleen whales off western Alaska and the central Aleutian Islands. *Deep-Sea Research Part I* 53:1772–1790.