
Alaska Journal of Anthropology

Volume 9, Number 2

2011





Alaska Journal of Anthropology

©2011 by the Alaska Anthropological Association: All rights reserved. ISSN 1544-9793

CORRESPONDENCE

Manuscript and editorial correspondence should be sent to:

Alaska Journal of Anthropology (AJA)

Attn: Editor

P.O. Box 241686

Anchorage, AK 99524

Telephone: (907) 336-0092

Fax: (907) 336-0093

Email: geoarch85@gmail.com

Manuscripts submitted for possible publication must conform with the AJA Style Guide, which can be found in AJA Volume 2(1-2):170-174 or on the Alaska Anthropological Association website (www.alaskaanthropology.org).

EDITORIAL BOARD

Barbara Crass	Associate Editor for Book Reviews, University of Wisconsin-Oshkosh
Christyann Darwent	University of California, Davis
Don Dumond	University of Oregon, Eugene
Norm Easton	Yukon College
Kerry Feldman	University of Alaska Anchorage
Erica Hill	University of Alaska Southeast
James Kari	University of Alaska Fairbanks
Herbert D. G. Maschner	Idaho State University
Rachel Mason	Associate Editor for Book Reviews, National Park Service
Karen Workman	University of Alaska Anchorage
William B. Workman	University of Alaska Anchorage
David R. Yesner	University of Alaska Anchorage

ALASKA ANTHROPOLOGICAL ASSOCIATION

BOARD OF DIRECTORS

Kerry Feldman	President	University of Alaska Anchorage
Karlene Leeper	Secretary	611th Wing, U.S. Air Force Anchorage Museum
Jenya Anichenko		Alaska State Historic Preservation Office
Joan Dale		Bureau of Land Management
Robin Mills		Anchorage
Monty Rogers		

OTHER ASSOCIATION OFFICIALS

Amy Steffian	Secretary	Alutiiq Museum
Rita Eagle	Secretary/Treasurer	Arctic Studies Center, Smithsonian Institution
Pat McClenahan	Newsletter Editor	Pacific Northwest Resources Consultants
Rick Reanier	<i>Aurora</i> Editor	Reanier & Associates
Owen Mason	Journal Editor	GeoArch Alaska and Institute of Arctic and Alpine Research
Ken Pratt	Assistant Editor	Bureau of Indian Affairs

MEMBERSHIP AND PUBLICATIONS

For subscription information, visit our website at www.alaskaanthropology.org. Information on back issues and additional association publications is available on page 2 of the subscription form. Please add \$8 per annual subscription for postage to Canada and \$15 outside North America.

Design and layout by Sue Mitchell, Inkworks
Copyediting by Erica Hill

TABLE OF CONTENTS

ARTICLES

- LATE HOLOCENE CHRONOLOGY OF THE NOATAK AND KOBUK RIVERS I
Scott Shirar
- NITROGEN ISOTOPE ANALYSIS IN THE ARCTIC: IDENTIFYING FISH PROCESSING AND MARINE RESOURCE
USE THROUGH ETHNOARCHAEOLOGICAL SOIL ANALYSIS ON NELSON ISLAND, ALASKA 17
Kelly J. Knudson and Liam Frink

REPORTS

- THE FAUNAL ASSEMBLAGE FROM AWA'UQ (REFUGE ROCK):
A UNIQUE RECORD FROM THE KODIAK ARCHIPELAGO, ALASKA. 55
Michael A. Etnier
- MIDDLE HOLOCENE HUMANS IN THE YUKON-CHARLEY RIVERS NATIONAL PRESERVE, ALASKA 65
Ian Buvit and Jeff Rasic
- "RETURN WITH A SHARING": COMING HOME TO THE KUSKOKWIM 73
Chris Wooley and Evelyn Thomas

BOOK REVIEWS

- the archaeology of north pacific fisheries*, EDITED BY MADONNA L. MOSS AND AUBREY CANNON 81
Reviewed by Michael A. Etnier
- ultimate americans: point hope, alaska, 1829–1909*, BY TOM LOWENSTEIN 83
Reviewed by Mark S. Cassell
- gwich'in athapaskan implements: history, manufacture, and usage according to
reverend david salmon*, BY THOMAS A. O'BRIEN 86
Reviewed by Norman Alexander Easton
- eldorado! the archaeology of gold mining in the far north*, EDITED BY CATHERINE HOLDER SPUDE,
ROBIN O. MILLS, KARL GURCKE, AND RODERICK SPRAGUE 88
Reviewed by Dael Devenport

LATE HOLOCENE CHRONOLOGY OF THE NOATAK AND KOBUK RIVERS

Scott Shirar

University of Alaska Museum of the North, Archaeology Department, 907 Yukon Drive, Fairbanks, Alaska 99775-6960;
sjshirar@alaska.edu.

ABSTRACT

There have been few contributions to a late Holocene chronology for Northwest Alaska since Giddings' early dendrochronology work in the 1940s and 1950s, which helped define the "Arctic Woodland Culture" along the Kobuk River. This paper contributes thirty radiocarbon dates to a late Holocene site chronology for interior Northwest Alaska, which includes dates from five sites and fourteen semisubterranean houses. The accuracy of the existing chronology is evaluated by carbon dating five of the same houses that Giddings analyzed using dendrochronology.

INTRODUCTION

The Noatak and Kobuk rivers both drain portions of the Brooks Range into Hotham Inlet in Kotzebue Sound (Fig. 1). Today each river serves as an important travel corridor connecting the coastal and interior portions of Northwest Alaska; this was likely true prehistorically as well. Currently there is a general lack of chronological data for late Holocene (i.e., ad 1000–1900) archaeological sites along the Noatak River, with only a handful of sites investigated and no regional-scale analyses to date (DeAngelo 2001; Gilbert-Young 2004; Hall 1969, 1971; Shirar 2007, 2009). More data are available for late Holocene sites along the Kobuk River based on J. Louis Giddings' pioneering archaeological and dendrochronological work in the 1940s and 1950s, but there is little data for the Kobuk region (Anderson 1983, 1988; Giddings 1941, 1942, 1944, 1948, 1952; Hickey 1968, 1976, 1977, 1979). The lack of new chronological data for late Holocene sites of interior Northwest Alaska is addressed here with the addition of thirty radiocarbon dates from three sites in the Kobuk River valley (Ahteut, Ekseavik, and Ambler Island) and two sites in the Noatak River valley (Maiyumerak Creek and Lake Kaiyak) (Fig. 1).

Beyond contributing to a late Holocene site chronology for each of these river valleys, this paper evaluates the relationship between dendrochronology and radiocarbon dating to see if it is possible to directly compare dates de-

rived from each method. Giddings' (1952) dendrochronology for sites in the Kobuk River valley is based on tree-rings from white spruce (*Picea glauca*), a species that is completely absent from the middle and upper portions of the Noatak. This circumstance makes it impossible to compare sites from each valley using dendrochronology alone. To remedy this situation, I tested the relationship between dendrochronology dates from the Kobuk and radiocarbon dates from the Noatak by radiocarbon dating five of the same Kobuk houses that Giddings previously dated using tree rings. If the calibrated radiocarbon dates from these houses at least partially overlap with the dendrochronology dates, then direct comparison of the two dating methods is a suitable technique for current and future research efforts. I also report on a test of the occupation dates of several sites and houses that Giddings determined using dendrochronology.

REGIONAL ECOLOGY

The Kobuk River exists largely within a boreal forest or taiga environment, while the Noatak River flows through a mostly treeless tundra environment, except in its lower portions. Despite the fact that trees are an abundant resource along the Kobuk and nearly absent along the Noatak, many of the same plant and animal species exist

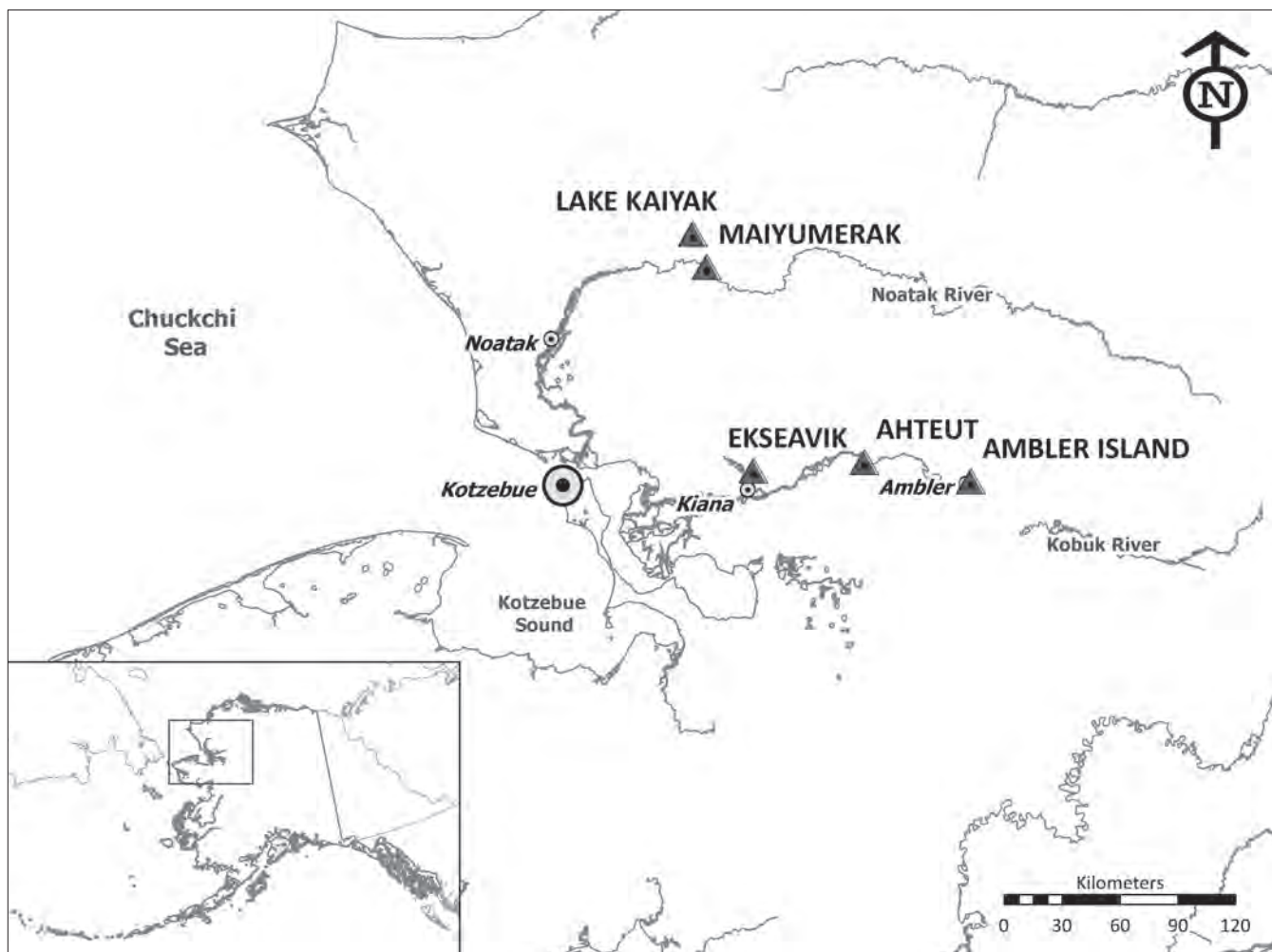


Figure 1. Map of Northwest Alaska showing the location of the Noatak and Kobuk River valleys and the location of each site discussed in the study. Map produced by Chris Houlette and edited by Sam Coffman.

in both valleys (Anderson et al. 1977; Gardner 1974; Kunz et al. 1984; Manuwal 1974; National Park Service 1986a, 1986b; Schroeder 1996; Young 1974). One key difference between the local ecology of each valley is the density, timing, and extent of salmon, trout, and sheefish runs. Large numbers of these fish spawn in the Kobuk River and its tributaries beginning in early summer through the fall. Ethnographically this abundance of fish is known to serve as the subsistence base throughout the year (Anderson et al. 1977; Burch 1998:158; Giddings 1956). Smaller numbers of fish make spawning runs to the upper Noatak River and for a shorter period of time during the summer. While still important ethnographically, fish were a less significant resource for this area when compared to caribou (Burch 1998:100–101).

Settlement, seasonality, land use, subsistence, and technological development in Northwest Alaska are

directly related to fluctuations in climate and resource availability throughout the late Holocene. Several models of late Holocene climate fluctuation have been produced using proxy data specific to Northwest Alaska. These records are based on beach ridge development at coastal locations (Cape Espenberg and Cape Krusenstern), soil development at specific archaeological sites (Iyatayet and Onion Portage), expansion and contraction of the Great Kobuk Sand Dunes, and the tree-ring records for the Kobuk River valley and Seward Peninsula (D'Arrigo et al. 2005; Giddings 1941, 1942, 1944, 1948, 1952; Graumlich and Gerlach 1992; Graumlich and King 1997; Mann et al. 2002; Mason 1990; Mason and Gerlach 1995; Mason and Jordan 1991). The role of climate fluctuation in late Holocene cultural development, whether significant or not, cannot be fully realized until a robust chronology is achieved.

A current working hypothesis regarding settlement and subsistence states that intervals of cold, stormy coastal conditions in Northwest Alaska during the past one thousand years forced human populations to inland locales (Murray et al. 2003:101–102). The development of a radiocarbon chronology for the past millennium will permit this hypothesis to be tested as new sites and individual features are temporally linked to climate conditions. If climate fluctuations were significant enough to affect local ecology, then human settlement should presumably shift, which should also be reflected in artifact and faunal assemblages.

LATE HOLOCENE ARCHAEOLOGY OF NORTHWEST ALASKA

Some of the first archaeological research accomplished in Northwest Alaska was during the 1940s when J. Louis Giddings conducted excavations at five late Holocene sites, each located either inland near the Kobuk River or on the coast near the town of Kotzebue. House timbers were collected at each site and a 970-year tree-ring record was created, allowing for these sites to be precisely dated (Giddings 1941, 1942, 1944, 1948, 1952; Graumlich and King 1997; Nash 2000). Giddings then used these dates to assemble a chronology for the region (e.g., Giddings 1952). As Giddings defined it, the Arctic Woodland Culture advanced over 500 years through six periods: Ahteut (AD 1250), Ekseavik (AD 1400), Old Kotzebue (AD 1400), Intermediate Kotzebue (AD 1550), Ambler Island (AD 1730–1760), and the Historic Aspect (Giddings 1952:9). Giddings' monograph remains the primary source for late Holocene archaeological research in Northwest Alaska, and today sites are still discussed in terms of how they relate to Giddings' Arctic Woodland chronology.

Beyond testing at Kotzebue, Ahteut, Ekseavik, and Ambler Island, Giddings (1952) recorded several other late Holocene sites during his pioneering work along the Kobuk River. Work continued in the valley throughout the 1960s at the Onion Portage, Kayák, and Ivisahpat sites, but little work was accomplished during the 1970s (Anderson 1988; Giddings 1962; Hickey 1968, 1977). In the 1980s the National Park Service began managing portions of the Kobuk River valley resulting in numerous archaeological projects that identified several late Holocene sites (Kunz 1984 et al.; Shirar 2010, 2012). Since Giddings' early work, just five late Holocene sites have been dated using either radiocarbon or dendrochronology: Onion Portage, the

Kayák site, the Ivisahpat site, AMR-220, and AMR-223 (Anderson 1988; Hickey 1968, 1977; Shirar 2010).

In the Noatak River valley, only four late Holocene sites have been systematically investigated. The first site excavated was Kangiguksuk in the 1960s (Hall 1971), followed by the Sapun Creek site in the 1990s (DeAngelo 2001), the Lake Kaiyak site, also in the 1990s (Gilbert-Young 2004), and the Maiyumerak Creek site in 2006 (Shirar 2007, 2009). Based on one dendrochronology sample and artifact comparisons to Giddings' Arctic Woodland sites, the occupations at Kangiguksuk and Sapun Creek are interpreted as sixteenth century. Given the small dendrochronology sample size and issues related to dating based on artifact style (see Murray et al. 2003), the temporal placement of these two sites is tentative. Two houses at the Lake Kaiyak site are radiocarbon dated. House 1 likely dates to the fifteenth or sixteenth century and House 2 could date anywhere between the 1400s and 1700s (Table 1). Seven features at the Maiyumerak Creek site are dated using radiocarbon and show that this site was occupied intermittently throughout much of the late Holocene (Table 1).

Our knowledge of how land use and settlement patterns relate to the late Holocene chronologies from the Noatak and Kobuk is incomplete. Giddings (1952:113) made seasonal interpretations for the sites he studied along the Kobuk River based on the artifact assemblages and noted that "people wintering on the middle river have at all times practiced a certain amount of sealing on the coast." Each of the four sites on the Noatak River are interpreted as spring, fall, and/or winter habitations. The late Holocene summer pattern is unknown, although each site does exhibit a small amount of sea mammal fauna and hunting equipment indicating ties to the coast (DeAngelo 2001; Gilbert-Young 2004; Hall 1971; Shirar 2007, 2009).

Ethnographically, people from the middle and upper Noatak River valley would travel to the coast during the summer to fish, hunt sea mammals, and trade before travelling back upriver in the early fall (Burch 1998:91–95). It makes sense to recover small amounts of sea mammal remains and related hunting gear at inland sites occupied by people who spent several months of each year on the coast. During the last millennium it is possible that people in Northwest Alaska followed a seasonal round similar to the eighteenth- and nineteenth-century ethnohistoric patterns described by Burch (1998, 2006). Before any meaningful conclusions can be drawn, this hypothesis needs

Table 1: Radiocarbon dates and associated information for late Holocene sites in interior Northwest Alaska

Lab #	Catalog Number ¹	Artifact Type	Material	$\delta^{13}\text{C}$	Conventional ^{14}C Age	2 σ Calibrated Age Ranges ²	Provenience	Dendrochronology Dates (# of samples) ³
Beta-223358	NOAT 29822	N/A	caribou bone	19.5‰	280 \pm 40 ^{14}C yrs BP	cal AD 1485–1668 (95.2%) cal AD 1781–1797 (4.4%) cal AD 1947–1950 (0.4%)	Maiyumerak House 8 (MY8)	N/A
Beta-228015	NOAT 29942	N/A	caribou bone	20.2‰	280 \pm 40 ^{14}C yrs BP	cal AD 1485–1668 (95.2%) cal AD 1781–1797 (4.4%) cal AD 1947–1950 (0.4%)	Maiyumerak House 8 (MY8)	N/A
Beta-223359	NOAT 29941	N/A	caribou bone	19.3‰	170 \pm 50 ^{14}C yrs BP	cal AD 1652–1711 (20.1%) cal AD 1716–1891 (62.4%) cal AD 1909–1953 (17.5%)	Maiyumerak House 8 (MY8)	N/A
Cams-142693	NOAT 29941	N/A	caribou bone	19.5‰	325 \pm 40 ^{14}C yrs BP	cal AD 1468–1647	Maiyumerak House 8 (MY8)	N/A
Beta-76675	NOAT 3214	N/A	unidentified charcoal	27.3‰	780 \pm 100 ^{14}C yrs BP	cal AD 1031–1355 (91.6%) cal AD 1345–1393 (8.4%)	Maiyumerak House 8 (MY8)	N/A
Beta-228016	NOAT 28090	N/A	<i>Populus</i> or <i>Salix</i> charcoal	26.5‰	520 \pm 40 ^{14}C yrs BP	cal AD 1316–1355 (22.0%) cal AD 1388–1447 (78.0%)	Maiyumerak House 8 (MY8)	N/A
Cams-141646	UA 1-1947-124	metapodial scraper	caribou bone	19.3‰	615 \pm 30 ^{14}C yrs BP	cal AD 1294–1401	Ekseavik House 11 (EK11)	AD 1279–1410 (43) ⁴
Cams-141647	UA 1-1947-125	metapodial scraper	caribou bone	18.2‰	735 \pm 20 ^{14}C yrs BP	cal AD 1256–1290	Ekseavik House 11 (EK11)	AD 1279–1410 (43)
Cams-141648	UA 1-1941-399	ice pick	caribou antler	17.8‰	710 \pm 25 ^{14}C yrs BP	cal AD 1262–1300 (94.3%) cal AD 1369–1381 (5.7%)	Ekseavik House 1 (EK1)	AD 1365–1384 (4)
Cams-141649	UA 1-1941-1661	metapodial scraper	caribou bone	18.5‰	815 \pm 30 ^{14}C yrs BP	cal AD 1170–1268	Ekseavik House 1 (EK1)	AD 1365–1384 (4)
Cams-141640	UA 1-1941-1716	metapodial scraper	caribou bone		830 \pm 35 ^{14}C yrs BP	cal AD 1058–1064 (0.7%) cal AD 1067–1071 (0.5%) cal AD 1155–1272 (98.8%)	Ahreut House 10s (AH10s)	AD 1202–1242 (5) (AH3n) ⁵
Cams-141641	UA 1-1941-1717	metapodial scraper	caribou bone	19.1‰	840 \pm 35 ^{14}C yrs BP	cal AD 1052–1080 (4.9%) cal AD 1129–1132 (0.5%) cal AD 1153–1268 (94.6%)	Ahreut House 10s (AH10s)	AD 1202–1242 (5) (AH3n)
Cams-141642	UA 1-1941-2774	metapodial scraper	caribou bone	18.6‰	325 \pm 30 ^{14}C yrs BP	cal AD 1480–1644	Ambler Island House 2 (AI2)	AD 1684–1754 (4)
Cams-141645	UA 1-1941-2893	awl	caribou bone	19.2‰	370 \pm 25 ^{14}C yrs BP	cal AD 1449–1524 (60.5%) cal AD 1558–1631 (39.5%)	Ambler Island House 2 (AI2)	AD 1684–1754 (4)

Table 1 (continued)

Lab #	Catalog Number ¹	Artifact Type	Material	$\delta^{13}\text{C}$	Conventional ^{14}C Age	2 σ Calibrated Age Ranges ²	Provenience	Dendrochronology Dates (# of samples) ³
Cams-141643	UA 1-1941-2775	metapodial scraper	caribou bone	17.3‰	265 \pm 35 ^{14}C yrs BP	cal AD 1494–1601 (42.3%) cal AD 1616–1672 (46.4%) cal AD 1778–1799 (9.8%) cal AD 1942–1951 (1.5%)	Ambler Island House 11 (AI11)	AD 1761 (1)
Cams-141644	UA 1-1941-2815	metapodial scraper	caribou bone	18.1‰	390 \pm 30 ^{14}C yrs BP	cal AD 1441–1523 (72.8%) cal AD 1559–1562 (0.6%) cal AD 1571–1630 (26.6%)	Ambler Island House 11 (AI11)	AD 1761 (1)
Beta-223360	NOAT 29725	N/A	caribou bone	20.4‰	360 \pm 40 ^{14}C yrs BP	cal AD 1450–1532 (48.2%) cal AD 1536–1635 (51.8%)	Maiyumerak House 1	N/A
Beta-223361	NOAT 29479	N/A	caribou bone	19.5‰	130 \pm 40 ^{14}C yrs BP	cal AD 1670–1780 (41.3%) cal AD 1798–1896 (41.6%) cal AD 1902–1944 (16.1%) cal AD 1950–1953 (1.0%)	Maiyumerak House 3	N/A
Beta-223362	NOAT 29793	N/A	caribou bone	18.8‰	470 \pm 50 ^{14}C yrs BP	cal AD 1320–1350 (4.7%) cal AD 1391–1518 (91.5%) cal AD 1594–1618 (3.8%)	Maiyumerak House 4	N/A
Beta-223363	NOAT 29749	N/A	caribou bone	18.8‰	620 \pm 40 ^{14}C yrs BP	cal AD 1288–1405	Maiyumerak House 6	N/A
Beta-223364	NOAT 29411	N/A	caribou bone	19.4‰	360 \pm 40 ^{14}C yrs BP	cal AD 1450–1532 (48.2%) cal AD 1536–1635 (51.8%)	Maiyumerak House 7	N/A
Beta-223365	NOAT 29767	N/A	caribou bone	18.5‰	270 \pm 40 ^{14}C yrs BP	cal AD 1486–1675 (90.3%) cal AD 1769–1799 (8.2%) cal AD 1941–1951 (1.5%)	Maiyumerak House 9	N/A
Beta-223366	NOAT 29672	N/A	caribou bone	19.1‰	260 \pm 40 ^{14}C yrs BP	cal AD 1491–1602 (38.8%) cal AD 1613–1681 (43.2%) cal AD 1739–1744 (0.5%) cal AD 1763–1802 (14.6%) cal AD 1938–1951 (2.9%)	Maiyumerak Locus 3	N/A
Beta-223367	NOAT 29313	N/A	caribou bone	19.3‰	270 \pm 40 ^{14}C yrs BP	cal AD 1486–1675 (90.3%) cal AD 1769–1799 (8.2%) cal AD 1941–1951 (1.5%)	Maiyumerak Locus 3	N/A
Beta-223368	NOAT 29594	N/A	caribou bone	19.4‰	380 \pm 40 ^{14}C yrs BP	cal AD 1442–1529 (58.1%) cal AD 1543–1634 (41.9%)	Maiyumerak Locus 3	N/A
Beta-223369	NOAT 29340	N/A	caribou bone	19.3‰	310 \pm 40 ^{14}C yrs BP	cal AD 1472–1653	Maiyumerak Locus 3	N/A

(continued on next page)

Table 1 (continued)

Lab #	Catalog Number ¹	Artifact Type	Material	$\delta^{13}\text{C}$	Conventional ¹⁴ C Age	2 σ Calibrated Age Ranges ²	Provenience	Dendrochronology Dates (# of samples) ³
Cams-141635	NOAT 5118	N/A	caribou bone	19.1‰	385 ± 30 ¹⁴ C yrs BP	cal AD 1443–1524 (68.8%) cal AD 1558–1564 (1.3%) cal AD 1569–1631 (29.9%)	Lake Kayak House 1	N/A
Cams-141638	NOAT 5719	N/A	caribou bone	19.0‰	400 ± 30 ¹⁴ C yrs BP	cal AD 1437–1522 (80.4%) cal AD 1574–1585 (1.9%) cal AD 1586–1625 (17.7%)	Lake Kayak House 1	N/A
Cams-141636	NOAT 5214-2	N/A	caribou bone	19.2‰	245 ± 30 ¹⁴ C yrs BP	cal AD 1523–1571 (9.9%) cal AD 1630–1681 (58.2%) cal AD 1739–1744 (0.4%) cal AD 1763–1802 (27.0%) cal AD 1938–1951 (4.5%)	Lake Kayak House 2	N/A
Cams-141637	NOAT 5214-95	N/A	caribou bone	20.0‰	405 ± 30 ¹⁴ C yrs BP	cal AD 1434–1521 (84.2%) cal AD 1575–1583 (1.3%) cal AD 1590–1623 (14.5%)	Lake Kayak House 2	N/A

1 NOAT catalog numbers are National Park Service and UA catalog numbers are University of Alaska Museum of the North.

2 All samples were calibrated using Calib ¹⁴C Radiocarbon Calibration Program (Stuiver et al. 2006) using the IntCal09 atmospheric curve (Reimer et al. 2009). Percentages are the relative area associated with the given range of the calibration curve for each date.

3 From Giddings (1952:105–110). Number of samples refers to the total number of dendrochronology samples recovered from a given provenience. Not all samples were dated by Giddings.

4 Ekseavik House 11 dendrochronology dates incorporate both Giddings (1952) and revised dates from Graumlich and King (1997).

5 No dendrochronology exists for Ahreut House 10s. Giddings (1952:108) dated the Ahreut site based on five samples from House 3n.

further testing and analysis. Data are needed from more late Holocene sites, not only from the Noatak and Kobuk River valleys, but also from coastal areas such as Cape Krusenstern, Kotzebue Sound, and Cape Espenberg.

SITE LOCATIONS AND DESCRIPTIONS

This paper focuses on five sites, the Ahteut, Ekseavik, and Ambler Island sites from the Kobuk River valley and the Maiyumerak Creek and Lake Kaiyak sites from the Noatak River valley (Giddings 1952; Gilbert-Young 2004; Shirar 2007, 2009). The Ahteut site is located along the middle portion of the Kobuk River approximately 96 km above the village of Kiana and 80 km below the village of Ambler (Fig. 1). The site is large and has designated north and south components consisting of an estimated 100+ house pits. Giddings (1952:27–29) excavated eight houses from the south portion of the site and four from the north portion. The Ahteut site is the oldest of the three sites on the Kobuk and exhibited the least amount of wood preservation, presumably due to its older age and a lack of permafrost at the site. Because of this poor preservation, few suitable dendrochronological samples were collected. Giddings (1952:108) dated Ahteut based on only five samples, all recovered from House 3n. Based on these five tree-ring dates, which range between AD 1202 and 1250, Giddings estimated that the Ahteut site was occupied sometime around AD 1250.

The Ekseavik site is located approximately 13 km up the Squirrel River from its confluence with the Kobuk (Giddings 1952:25) (Fig. 1). The present-day village of Kiana is situated at this confluence, which is on the lower third of the river. Ekseavik consists of approximately twenty houses, eleven of which were fully excavated over the course of three field seasons (Giddings 1952:8). Most of the houses here were well preserved in permafrost and therefore yielded a total of ninety-nine tree-ring dates from seven different houses (H1, H2, H3, H7, H8, H9, and H11). Giddings calculated that these dates span approximately 125 years from the early AD 1300s to 1432, although subsequent work by Graumlich and King (1997) pushed the earliest date at Ekseavik back to AD 1279. The large number of samples available from Ekseavik allowed Giddings to more closely estimate the period of occupation for individual features; he concluded that the houses at this site were likely not occupied at the same time. Based on how the dendrochronological dates grouped together

and the similarity of material culture among the houses, Giddings believed that Ekseavik was primarily occupied around AD 1400.

The Ambler Island site is situated on an island in the Kobuk River near the village of Ambler, next to the Ambler River confluence (Fig. 1) and consists of fifteen houses, all of which were excavated (Giddings 1952:13). This site lacked a substantial amount of preserved wood and only twenty-three tree-ring dates were obtained from eight different houses (H1, H2, H3, H4, H8, H11, H12, H15) (Giddings 1952). These dates span almost 175 years and Giddings (1952:108) described the data they provided as “rather scanty.” Based on how these twenty-three dates group, Giddings believed there were two periods of building at the site, which occurred between AD 1730 and 1760.

The Maiyumerak Creek site is located along the middle portion of the Noatak River near its confluence with Maiyumerak Creek (Fig. 1). This site exhibits wood preservation, but in most cases it is poor and consists of cottonwood posts, which would be difficult and time consuming to compare to Giddings’ white spruce tree-ring record. In all cases the temporal placement of the Maiyumerak Creek site has relied on radiocarbon dating and all seven houses (H1, H3, H4, H6, H7, H8, H9) at the site have been dated (Table 1). Of these seven houses, only House 8 has been formally excavated and therefore more associated radiocarbon dates exist for this house. Six radiocarbon dates have been derived from both bone ($n = 4$) and charcoal ($n = 2$) samples collected from House 8. These dates indicate that this house was occupied at some point between cal AD 1500 and 1700 (Shirar 2007, 2009).

The Lake Kaiyak site is located on the southeast shore of Lake Kaiyak along the Kugururok River, which is a main tributary of the Noatak River. The site consists of eight house features with some associated caches and was originally recorded in the 1960s. Vandalism was discovered at the site in 1995 and excavations were conducted in 1996 to mitigate damage in two of the houses (H1 and H2) (Gilbert-Young 2004). Poor preservation of house timbers at the site prevented dendrochronological analysis and relative dating techniques provided the initial temporal placement of the site (Gilbert-Young 2004:18–19). Four radiocarbon dates are now available for Lake Kaiyak: two from the House 1 floor and two from the House 2 floor. The four dates indicate that both of these houses were likely occupied between cal AD 1450 and 1650.

RADIOCARBON DATING AND DENDROCHRONOLOGY

Redating some of the same houses that Giddings dated using dendrochronology provides a second, independent line of evidence to bear on Giddings' original conclusions regarding site occupation. One main issue with using only dendrochronology is that it dates the life of the tree rather than the human occupation of a site or feature. Giddings (1952:106) addressed this issue, noting that the houses on the Kobuk River were built using drift wood rather than freshly cut green logs. This means the wood incorporated into these features died weeks or months prior to the actual construction of the house. Another key point is that many late Holocene village sites, especially the larger ones, were likely multicomponent, meaning houses were occupied at different times.

Further complicating dendrochronological interpretations is the fact that structural wood may have been recycled during multiple occupations of a site or during multiple phases of house construction over a long period of time. Giddings (1952:107) writes: "Where only one construction log is dated for a house, we can only assume that building took place after the death (bark date) of this specimen. Actually, the house may have been occupied for some time before this log was added to bolster sagging walls." To circumvent this issue Giddings (1952:107) tried to use "a large number of bark dates for the walls of a single house," allowing him to make a "closer estimate of occupation, possible reconstruction, and abandonment."

Radiocarbon samples were chosen for this study using a protocol specifically set up for sites believed to date to the last millennium in Northwest Alaska. This protocol consists of three steps and is based on previous research designed to produce radiocarbon chronologies (Rieth and Hunt 2008). The first step was to make sure that each sample came from a secure and appropriate archaeological context. Since this chronology is based on dating semi-subterranean houses, the ideal archaeological context for a sample is a house floor. When dating a sample with only a general house provenience, there is some risk that the sample was collected from the roof or wall fall, meaning it could be associated with a different period of occupation and not with the house at all.

The decision to date wood, charcoal, or bone depends on which of these materials is available. As an example, at the Kobuk sites, charcoal and unmodified fauna went

largely uncollected; however, there are numerous bone and antler artifacts available for dating from each site. If more than one of these materials are present, then the types of species available affect which sample is chosen to date. For wood and charcoal, the "old wood" effect in the Arctic means that the driftwood used in house construction or as fuel may have died decades earlier. There are also long-lived species such as spruce where a date on heartwood could yield a date hundreds of years older than a date on a near-bark layer. When dating wood or charcoal, it is important to use samples of short-lived species such as willow (e.g., *Salix* spp.) or to date an outer wood layer when dealing with long-lived species (Arundale 1981; Dean 1978; Schiffer 1986).

Dating marine mammal bone can be problematic due to fractionation, which yields dates younger than they actually are. The marine reservoir effect is also a concern and yields dates older than they actually are (Arundale 1981). Researchers have found that dating bone samples with a low collagen yield as a result of poor preservation can also produce unreliable dates (van Klinken 1999; Weber et al. 2005). In lieu of a percent collagen figure, another way to assess the quality of bone and antler preservation is through an evaluation of stable carbon ($\delta^{13}\text{C}$), which is a standard figure reported with radiocarbon results (Nelson and Møhl 2003).

Each archaeological context (or each house) was dated a minimum of two times and from different samples when possible. Having at least two dates from each house increases the probability that one is an accurate date. If a suite of dates (two or more) from a given context are calibrated and still overlap, then this bolsters confidence that no outlying dates are included in the chronology (Rieth and Hunt 2008). This tactic is especially important for sites within the last one thousand years, where there are large fluctuations in the radiocarbon calibration curve and a single date can span several hundred nonconsecutive years.

A total of ten bone and antler samples collected from five separate houses representing the three sites within the Kobuk River valley were chosen for radiocarbon analysis (Table 1). During excavation there were no contextual distinctions made between house roof, wall fall, or floor in the five Kobuk River house features, meaning that samples had only a general house context, a common problem when working with older collections. Since the Kobuk River houses only have a general structure provenience, bone and/or antler artifacts were dated in order to

strengthen the link to human occupation of the houses. The non-diagnostic artifacts that were dated include: eight caribou metapodial scrapers, one bone awl carved from a caribou metapodial, and an ice or root pick made from caribou antler (Fig. 2).

Sixteen dates exist for the Maiyumerak Creek site and all are included in the chronology (Table 1). Six of these dates are derived from House 8 samples of either charcoal ($n = 2$) or unmodified caribou bone ($n = 4$). Five of the six samples from House 8 were collected from the floor and fit with the protocol outlined above. After calibration, the two charcoal dates from House 8 are about 100 years earlier than the dates on caribou bone. This indicates that either the house was lived in for decades and that these dates are from the early years of the occupation or that old wood was used during house construction or subsequent rebuilding.

The other ten dates from Maiyumerak are all on unmodified caribou bone collected from house floors or from the lowest levels of a midden deposit (Maiyumerak Locus 3). There is one date from each of six houses. All ten dates were derived from well-preserved caribou bone or antler to avoid some of the pitfalls associated with dating old wood. Caribou bone is often plentiful at late Holocene sites in Northwest Alaska. Dates on this material do not need to be corrected for the marine reservoir effect.

Four radiocarbon dates are available from two different house features at the Lake Kaiyak site and are included in Table 1. Two of these dates are associated with House 1 and two from House 2. All four are from samples of unmodified caribou bone, which are independent elements recovered from the respective house floors.

RADIOCARBON RESULTS

Table 1 presents thirty radiocarbon dates from late Holocene sites in the Kobuk and Noatak valleys and five dendrochronology dates from the houses in the Kobuk valley dated by Giddings. Four of the fourteen houses listed in the table are directly associated with a range of dendrochronology dates. Giddings dated the Ahteut site based on five dendrochronology samples from House 3n, meaning that the radiocarbon dates for House 10s in Table 1 cannot be directly compared to Giddings dendrochronology. Generally speaking, most of the radiocarbon dates match up well with the dates derived from house timbers (Giddings 1952:105–110; Graumlich and King 1997). All four of the radiocarbon dates from the Ambler

Island site, however, trend approximately 50 to 100 years older. This same trend is apparent with one of the four radiocarbon dates from Ekseavik. The percent of collagen recovered from the bone samples used in this study was not reported by the lab, but all of the dates run on bone are from terrestrial mammals with stable carbon values that indicate each sample was well preserved (Table 1).

There are several scenarios that could account for these differences. The first relates to the lack of contextual information for the dated artifacts. These houses could have been occupied periodically over the course of a century and thus seen episodes of abandonment and reoccupation associated with rebuilding and/or renovation events. The older dates could simply be a result of dating artifacts that are actually associated with an older occupation of the house. The radiocarbon results in Table 1 show that many late Holocene village sites, like Maiyumerak, are multi-component and that not all of the houses were occupied during the same time period. These results also suggest that many of these late Holocene sites were likely occupied concurrently and do not necessarily represent sequential occupation, which illustrates the importance of dating individual features. This point is underscored with the fact that after radiocarbon dating, the occupations at Ahteut and Ekseavik were determined to be multicomponent and overlapping and cannot be viewed as strictly sequential.

These date discrepancies could also be a result of problems with dendrochronology and tree-ring sampling. There could have been older structural wood from some of these houses that was not preserved and therefore is not represented in Giddings' chronology. Several of the houses Giddings dated had as few as one house timber preserved well enough to provide a date. Small sample sizes like this can produce less than reliable chronologies, which is often a problem early in the dendrochronology sequencing process. Early dendrochronology sequences like this one, with small regional sample sizes, also have problems with the dropping or adding of rings. This happens when a tree either does not produce a ring or produces two rings for a given year, which can result in inaccurate dates (Baillie 1982:52; Stokes and Smiley 1996:13–18). Some of these sample size issues have been addressed in subsequent work by Graumlich and King (1997), but there is still more work that could be done to make this sequence more reliable.

Graumlich and King (1997) added new specimens from living trees to the Kobuk River valley sequence

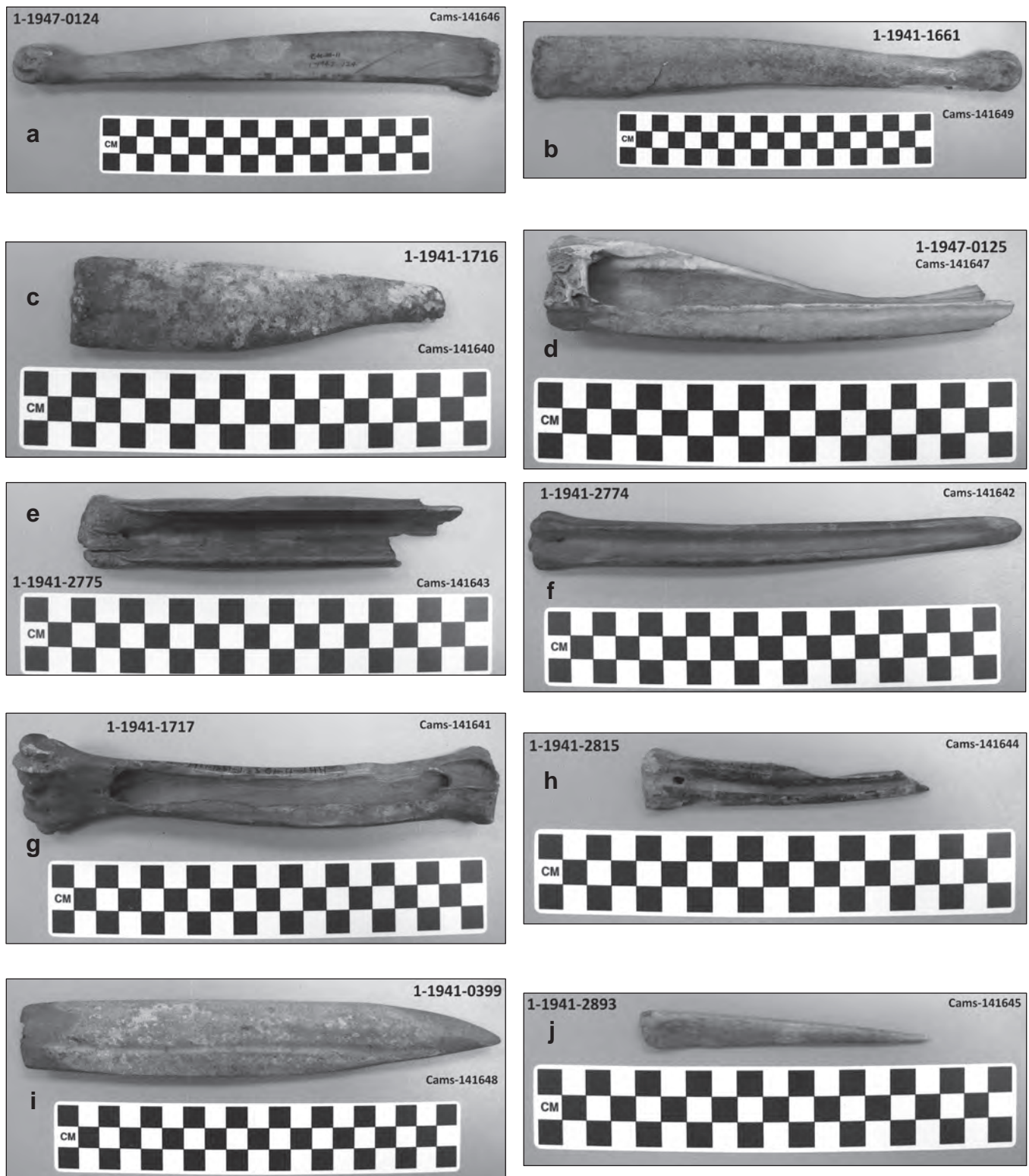


Figure 2. Artifacts used to date Kobuk River houses. Objects *a* through *h* are scrapers made from the metapodial bone of a caribou; *i*, ice pick of antler; *j*, caribou bone awl.

but also reanalyzed 102 of Giddings' 150+ archaeological specimens. Through this tree-ring reanalysis, the oldest date for Ekseavik House 11 was pushed back from AD 1300 to AD 1279. This alteration means that one of the radiocarbon dates now overlaps with the tree-ring dates. This provides an example of how important it will be to continue to refine and reanalyze Giddings' archaeological tree-ring samples and to sort out which samples come from which houses.

The issues related to dendrochronology and small sample size are well illustrated with the data presented in Table 1. House 11 at Ekseavik has 43 dendrochronology samples and these dates are nearly identical to the cali-

brated radiocarbon dates for this house. The three other houses from the Kobuk have four or less dendrochronology samples and the radiocarbon dates tend to range older than the dendrochronology dates. This demonstrates the importance of having a large dendrochronology sample size and cross-checking dates with radiocarbon whenever possible. These results indicate that there are older occupations in these houses that are not showing up in the dendrochronology either because of small sample size or because of rebuilding and reuse.

Even though not all of the radiocarbon dates overlap perfectly with the tree-ring dates, both data sets illustrate the same general site chronology. Fig. 3 presents the

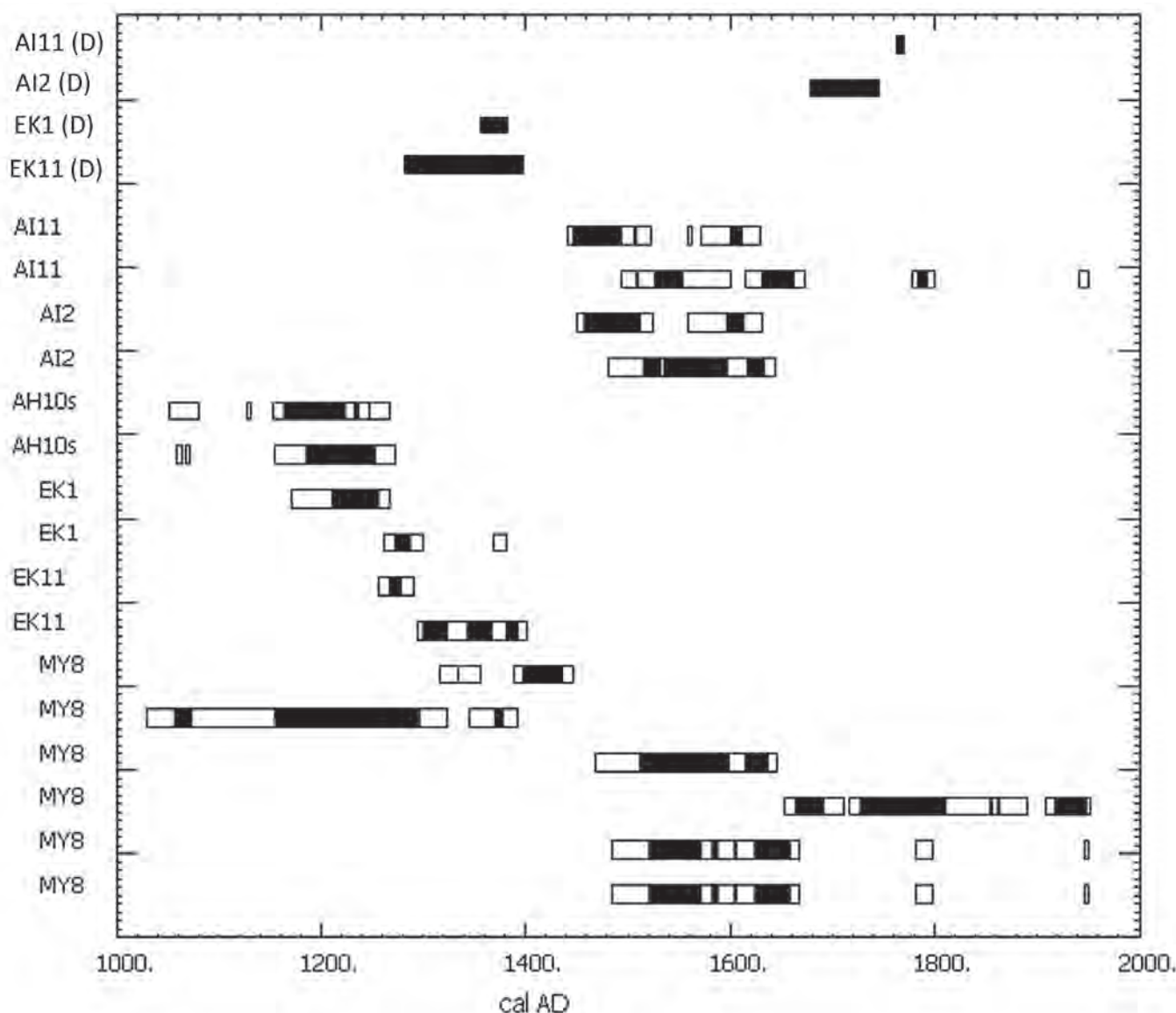


Figure 3. Dendrochronology dates and calibrated age probability curves for radiocarbon dates from Ambler Island, Abteut, Ekseavik, and Maiyumerak Creek House 8. Radiocarbon dates calibrated with CALIB Radiocarbon Calibration Program (Stuiver et al. 2006) using the IntCal09 atmospheric curve (Reimer et al. 2009).

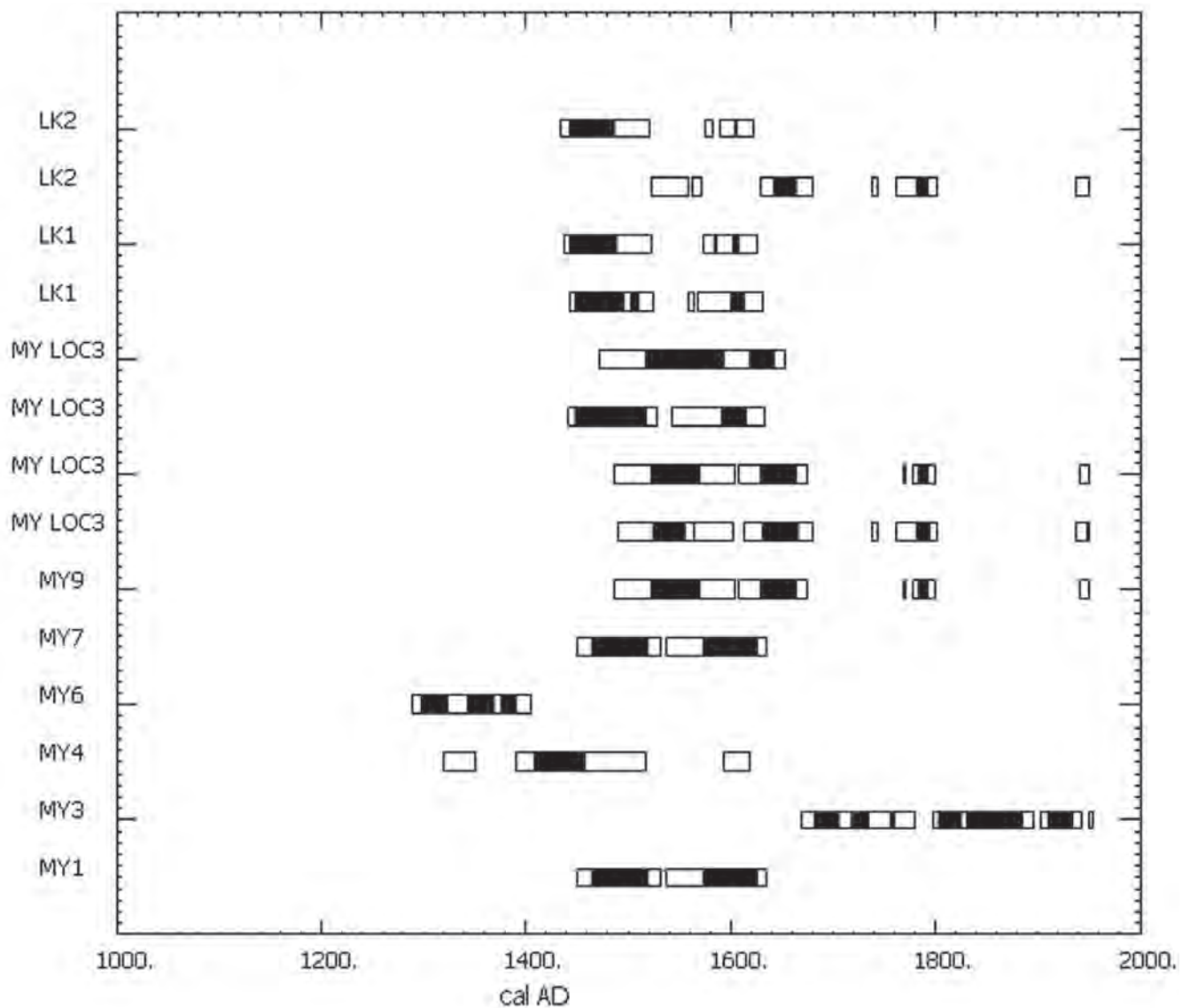


Figure 4. Calibrated age probability curves for radiocarbon dates of various houses and midden deposit at Maiyumerak Creek and Lake Kayak. Radiocarbon dates calibrated with CALIB Radiocarbon Calibration Program (Stuiver et al. 2006) using the IntCal09 atmospheric curve (Reimer et al. 2009).

radiocarbon results for House 8 at Maiyumerak and for the five Kobuk River houses along with the four dendrochronology dates. House 10s at the Ahteut site is the oldest feature and was likely occupied between cal AD 1100 and 1300. The two houses from the Ekseavik site were likely occupied between cal AD 1200 and 1400, followed by the two houses from the Ambler Island site, which were occupied between cal AD 1500 and 1700. The radiocarbon dates on caribou bone from House 8 at the Maiyumerak Creek site also indicate a cal AD 1500 to 1700 occupation, which overlaps with the dates from Ambler Island.

The dates on charcoal from House 8 are at least 50 to 100 years older than the dates on bone collagen, which

is likely a result of dating old wood. Beta-76675, which produced the oldest date, was collected from the eroding bank during the initial discovery of the site and the wood species was never identified. Beta-228016 was identified as either willow or cottonwood and was collected from the floor of House 8. The date on this sample is within a couple of decades of the bone dates, which is well within the life span of either willow or cottonwood.

The six other houses that were dated at Maiyumerak Creek show that this site was occupied throughout much of the late Holocene between cal AD 1290 and 1900 (see Table 1 and Fig. 4). Four dates were run on samples from the extensive midden deposits in Locus 3 at Maiyumerak

and all four overlap roughly between cal AD 1450 and 1650. The four dates from the two houses at Lake Kaiyak overlap between approximately cal AD 1450 and 1650.

CONCLUSIONS AND FUTURE RESEARCH

These thirty radiocarbon dates (Table 1) are a significant contribution to the archaeology of the region and represent a starting point in creating a robust late Holocene chronology for interior Northwest Alaska. The dates reported here generally support Giddings' initial interpretation of when the Ekseavik, Ahteut, and Ambler Island sites were occupied, but also refine his analysis and expand the period of occupation at each site. The radiocarbon results also make it clear that the late Holocene chronology of the region is complex, since many of these village sites, especially the large ones, were likely occupied simultaneously over the course of centuries.

Data presented in this paper show that it is appropriate to directly compare dates derived from both radiocarbon and dendrochronology. With radiocarbon dating, it is critical to follow protocols regarding sample selection in order to create the strongest possible link between the date(s) and when people occupied a house or used a feature. Features dated with a large number of dendrochronology samples more closely overlap radiocarbon results from the same feature, highlighting the importance of using large sample sizes with dendrochronology.

The fact that a site such as Maiyumerak Creek shows an occupational period over the course of six hundred years illustrates the importance of evaluating house features individually. Each house feature at Maiyumerak was dated at least once; while many of these dates fall between cal AD 1450 and 1650, there are dates that range as old as cal AD 1290 and as young as cal AD 1900. Generally, as many features as possible should be dated at late Holocene sites; ideally, each would be dated at least twice through a combination of both radiocarbon and dendrochronology, assuming a house exhibits good preservation and timbers are available for analysis.

The chronology presented here should be viewed as a preliminary attempt to better understand when and where people were living in interior Northwest Alaska during the last thousand years. As more dates are added and the chronology grows, interior sites and their assemblages can more readily be placed into context. Only when this

context is properly established can archaeologists begin to understand the complexities of late Holocene settlement, land use, technology, and subsistence and how each relates to regional ecology and climate fluctuation during the last millennium.

ACKNOWLEDGEMENTS

This paper was originally presented in a symposium at the 36th annual meeting of the Alaska Anthropological Association in Juneau, Alaska in 2009. Numerous individuals helped me along the way with this research and I want to specifically thank Bob Gal, Eileen Devinney, Jeff Rasic, Dan Odess, Molly Proue, Jim Whitney, Chris Houlette, and Sam Coffman. I would also like to acknowledge Owen Mason, Erica Hill, Josh Reuther, and Brian Wygal for their editing and comments, but also Josh and Brian for organizing the 2009 symposium and inviting me to participate. Two anonymous reviewers also made insightful and thought-provoking comments that improved this paper. The National Park Service and the Otto William Geist Fund, administered through the University of Alaska Museum of the North, provided funding to complete this research.

REFERENCES

- Anderson, Douglas D.
1983 Changing Prehistoric Eskimo Subsistence Patterns: A Working Paper. In *Cultures of the Bering Sea Region: Papers from an International Symposium*, edited by Henry N. Michael and James W. VanStone, pp. 62–83. American Council of Learned Societies and Academy of Sciences of the USSR, New York.
- 1988 *Onion Portage: The Archaeology of a Stratified Site on the Kobuk River, Northwest Alaska*. Anthropological Papers of the University of Alaska 22(1–2):1–163.
- Anderson, Douglas D., Ray Bane, Richard K. Nelson, Wanni W. Anderson and Nita Sheldon
1977 *Kuuvaŋmiit Subsistence: Traditional Eskimo Life in the Latter Twentieth Century*. National Park Service, U.S. Department of the Interior, Washington, DC.
- Arundale, Wendy H.
1981 Radiocarbon Dating in Eastern Arctic Archaeology: A Flexible Approach. *American Antiquity* 46(2):244–271.

- Baillie, M. G. L.
1982 *Tree-Ring Dating and Archaeology*. University of Chicago Press, Chicago.
- Burch, Jr., Ernest S.
1998 *The Inupiaq Eskimo Nations of Northwest Alaska*. University of Alaska Press, Fairbanks.
2006 *Social Life in Northwest Alaska: The Structure of Inupiaq Eskimo Nations*. University of Alaska Press, Fairbanks.
- D'Arrigo, Rosanne, Erika Mashig, David Frank, Rob Wilson, and Gordon Jacoby
2005 Temperature Variability over the Last Millennium Inferred from Northwestern Alaska Tree Rings. *Climate Dynamics* 24(2-3):227-236.
- Dean, Jeffrey S.
1978 Independent Dating in Archaeological Analysis. In *Advances in Archaeological Method and Theory*, vol. 1, edited by Michael B. Schiffer, pp. 223-255. Academic Press, New York.
- DeAngelo, Rebekah
2001 Animal Procurement and Seasonality: A Study of Faunal Remains from a Prehistoric Sod House Ruin in Northwest Alaska. In *People and Wildlife in Northern North America: Essays in Honor of R. Dale Guthrie*, edited by S. Craig Gerlach and Maribeth S. Murray, pp. 188-199. BAR International Series 944. Archaeopress, Oxford.
- Gardner, A. L.
1974 Mammals of the Noatak River Valley. In *The Environment of the Noatak River Basin, Alaska*, edited by Steven B. Young, pp. 224-251. Center for Northern Studies, Wolcott, VT.
- Giddings, Jr., J. Louis
1941 Dendrochronology in Northern Alaska. *University of Alaska Publication* vol. 4, *Laboratory of Tree-Ring Research Bulletin* no. 1 and *University of Arizona Bulletin* 12(4).
1942 Dated Sites on the Kobuk River, Alaska. *Tree Ring Bulletin* 9(1):2-9.
1944 Dated Eskimo Ruins of an Inland Zone. *American Antiquity* 10(2):113-134.
1948 Chronology of the Kobuk-Kotzebue Sites. *Tree-Ring Bulletin* 14(4):26-32.
1952 *The Arctic Woodland Culture of the Kobuk River*. Museum Monographs, University Museum, University of Pennsylvania, Philadelphia.
1956 Forest Eskimos: An Ethnographic Sketch of Kobuk River People in the 1800s. *University Museum Bulletin* (Philadelphia) 20(2):1-61.
- 1962 Onion Portage and Other Flint Sites of the Kobuk River. *Arctic Anthropology* 1(1):6-27.
- Gilbert-Young, Sabra E.
2004 Archaeology of a Severely Vandalized Site, 49-MIS-032, at Lake Kaiyak, Noatak National Preserve, Northwest Alaska. Unpublished master's thesis, Department of Anthropology, Washington State University, Pullman, WA.
- Graumlich, Lisa J., and S. Craig Gerlach
1992 Reconstructing Temperature History from Tree Rings in Northwestern Alaska. *Arctic Research of the United States* 6:10-12.
- Graumlich, Lisa J., and John C. King
1997 Late Holocene Climatic Variation in Northwestern Alaska as Reconstructed from Tree Rings. A Final Report on Cooperative Research with the National Park Service. Unpublished manuscript, Laboratory of Tree-Ring Research, University of Arizona, Tucson.
- Hall, Jr., Edwin S.
1969 Avian Remains from the Kangiguksuk Site, Northern Alaska. *The Condor* 71:76-77.
1971 Kangiguksuk: A Cultural Reconstruction of a Sixteenth Century Eskimo Site in Northern Alaska. *Arctic Anthropology* 8(1):1-101.
- Hickey, Clifford G.
1968 The Kayak Site: An Analysis of the Spatial Aspect of Culture as an Aid to Archaeological Inference. Unpublished master's thesis, Department of Sociology and Anthropology, Brown University, Providence, RI.
1976 An Economic View of Adaptation. In *Contributions to Anthropology: The Interior Peoples of Northern Alaska*, edited by Edwin S. Hall, Jr., pp. 235-298. Mercury Series, Archaeological Survey of Canada, paper no. 49. National Museum of Man, Ottawa.
1977 Process in Prehistory: A Structural Analysis of Change in an Eskimo Culture. Unpublished Ph.D. dissertation, Department of Anthropology, Brown University, Providence, RI.
1979 The Historic Beringian Trade Network: Its Nature and Origins. In *Thule Eskimo Culture: An Anthropological Retrospective*, edited by Allen McCartney, pp. 411-434. National Museums of Canada, Ottawa.
- Kunz, Michael L., Peter G. Phippen, Richard E. Reanier, and Mark Standley
1984 Upper Kobuk River Drainage Archaeology. Report for Phase I of a Cultural Resources Survey

- and Inventory in Gates of the Arctic National Park and Preserve. National Park Service, Fairbanks.
- Mann, D. H., P. A. Heister, and B. P. Finney
2002 Holocene History of the Great Kobuk Sand Dunes, Northwestern Alaska. *Quaternary Science Reviews* 21:709–731.
- Manuwal, D. A.
1974 Bird Populations of the Noatak River Basin. In *The Environment of the Noatak River Basin, Alaska*, edited by Steven B. Young, pp. 252–325. Center for Northern Studies, Wolcott, VT.
- Mason, Owen K.
1990 Beach Ridge Geomorphology of Kotzebue Sound: Implications for Paleoclimatology and Archaeology. Unpublished Ph.D. dissertation, Department of Quaternary Science, University of Alaska Fairbanks.
- Mason, Owen K., and S. Craig Gerlach
1995 Chukchi Hotspots, Paleo-Polynyas, and Caribou Crashes: Climatic and Ecological Dimensions of North Alaska Prehistory. *Arctic Anthropology* 32(1):101–130.
- Mason, Owen K., and James W. Jordan
1991 A Proxy Late Holocene Climatic Record Deduced from Northwest Alaska Beach Ridges. In *Proceedings, International Conference on the Role of the Polar Regions in Global Change*, edited by G. Weller, C. Wilson, and B. Severin, pp. 649–657. Geophysical Institute, University of Alaska.
- Murray, Maribeth S., Aaron C. Robertson, and Rachel Ferrara
2003 Chronology, Culture, and Climate: A Radiometric Re-evaluation of Late Prehistoric Occupations at Cape Denbigh, Alaska. *Arctic Anthropology* 40(1):87–110.
- Nash, Stephen E.
2000 James Louis Giddings' Archaeological Tree-Ring Dating in the Arctic: A Forgotten Legacy. *Arctic Anthropology* 37(1):60–78.
- National Park Service
1986a Kobuk Valley National Park, Alaska. Report on the General Management Plan and Environmental Assessment, Land Protection Plan, Wilderness Suitability Review, and River Management Plan. National Park Service, Anchorage.
1986b Noatak National Preserve. Report on the General Management Plan, Land Protection Plan, and Wilderness Suitability Review. National Park Service, Anchorage.
- Nelson, D. E., and J. Møhl
2003 Radiocarbon Dating Caribou Antler and Bone: Are They Different? *Arctic* 56(3):262–265.
- Reimer, P. J., M. G. L. Baillie, E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E., Buck, G. S. Burr, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, I. Hajdas, T. J. Heaton, A. G. Hogg, K. A. Hughen, K. F. Kaiser, B. Kromer, F. G. McCormac, S. W. Manning, R. W. Reimer, D. A. Richards, J. R. Southon, S. Talamo, C. S. M. Turney, J. van der Plicht, and C. E. Weyhenmeyer
2009 IntCal09 and Marine09 Radiocarbon Age Calibration Curves, 0–50,000 Years Cal BP. *Radiocarbon* 51(4):1111–1150.
- Rieth, Timothy M., and Terry L. Hunt
2008 A Radiocarbon Chronology for Samoan Prehistory. *Journal of Archaeological Science* 35(7):1901–1927.
- Schiffer, Michael B.
1986 Radiocarbon Dating and the “Old Wood” Problem: The Case of the Hohokam Chronology. *Journal of Archaeological Science* 13(1):13–30.
- Schroeder, M.
1996 *Birds of the Northwest Alaska Areas*. National Park Service, Jamestown, ND.
- Shirar, Scott
2007 Maiyumerak Creek: Late Prehistoric Subsistence and Seasonality in Northwest Alaska. Unpublished master's thesis, Department of Anthropology, University of Alaska, Fairbanks.
2009 Subsistence and Seasonality at a Late Prehistoric House Pit in Northwest Alaska. *Journal of Ecological Anthropology* 13(1):6–25.
2010 Survey in Onion Portage National Historic Landmark: A Report on a 2010 National Park Service Challenge Cost-Share Agreement. Report on file at the National Park Service Regional Office, Anchorage, AK.
2012 Dunes Study Unit, Kobuk Valley National Park: Archaeological and Ethnographic Overview. Report on file at the National Park Service Regional Office, Anchorage, AK.
- Stokes, Marvin A., and Terah L. Smiley
1996 *An Introduction to Tree-Ring Dating*. University of Arizona Press, Tucson.
- Stuiver, M., P. J. Reimer, and R. Reimer
2006 CALIB Radiocarbon Calibration Program. Online at: <http://calib.qub.ac.uk/calib>. Accessed March 2, 2009.

- van Klinken, G.J.
1999 Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements. *Journal of Archaeological Science* 26:687–695.
- Weber, Andrzej, Hugh G. McKenzie, Roelf Beukens, and Olga I. Goriunova
2005 Evaluation of Radiocarbon Dates from the Middle Holocene Hunter-Gatherer Cemetery Khuzhir-Nuge XIV, Lake Baikal, Siberia. *Journal of Archaeological Science* 32:1481–1500.
- Young, Steven B.
1974 Vegetation of the Noatak River Valley. In *The Environment of the Noatak River Basin, Alaska*, edited by Steven B. Young, pp. 58–85. Center for Northern Studies, Wolcott, VT.

NITROGEN ISOTOPE ANALYSIS IN THE ARCTIC: IDENTIFYING FISH PROCESSING AND MARINE RESOURCE USE THROUGH ETHNOARCHAEOLOGICAL SOIL ANALYSIS ON NELSON ISLAND, ALASKA

Kelly J. Knudson

Archaeological Chemistry Laboratory, School of Human Evolution and Social Change, Arizona State University, PO Box 872402, Tempe, AZ 85287; kelly.knudson@asu.edu

Liam Frink

Department of Anthropology, University of Nevada at Las Vegas, 4505 Maryland Parkway, Box 455003, Las Vegas, NV 89154; lfrink@unlv.edu

ABSTRACT

Despite the importance of marine resources and seasonal fish processing in the past, their ephemeral natures hamper archaeological study. However, nitrogen isotope analysis of soils provides a new, minimally invasive method to identify marine resource procurement and processing in the archaeological record, and has potential for use in the Arctic and beyond. To aid researchers utilizing nitrogen isotope analysis in the Arctic, we first present a comprehensive overview of published nitrogen isotope data in the Arctic. We then present nitrogen isotope data ($\delta^{15}\text{N}$) from ethnoarchaeological soils from known fish processing areas and a historic semisubterranean structure in Tununak, Nelson Island, Alaska. In addition to presenting isotopic floral and faunal baseline data, we demonstrate that, compared to offsite samples [mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.2\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 35$)], soils from fish processing areas were significantly more enriched in ^{15}N [mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.4\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 49$)]. Soil samples collected from an abandoned semisubterranean structure where marine products were processed and stored [mean $\delta^{15}\text{N}_{(\text{AIR})} = 6.8\text{‰} \pm 0.2\text{‰}$ (1σ , $n = 105$)] were also significantly enriched in ^{15}N .

INTRODUCTION

Despite the importance of marine resources in the Arctic, the ephemeral nature of fish and marine resource processing areas can make them difficult to identify. However, biogeochemical analyses of archaeological soils have become important tools to identify archaeological sites and activities (see overviews in Holliday et al. 2010; Lopez Varela and Dore 2010; Walkington 2010). For example, multi-elemental characterizations of archaeological soils have been used to identify past activities, including fish processing (e.g., Entwistle et al. 2007; Knudson and Frink 2010a; Knudson et al. 2004; Middleton and Price 1996; Misarti et al. 2011; Terry et al. 2004; Wells 2004; Wilson et al. 2008). However, the behavior and concentrations of

anthropogenically deposited metals will fluctuate depending on the chemical, biological and physical characteristics of the site and soil (Haslam and Tibbett 2004). In addition, many regions do not have modern sites that can provide ethnoarchaeological soil samples from known activity areas for comparison with archaeological samples.

We argue that soil nitrogen isotope analysis can identify past use of marine products, which in turn may help elucidate subsistence behaviors at ephemeral sites, particularly in areas where large excavations are not possible. In archaeology, the application of nitrogen isotope analysis has a long history. Nitrogen isotopes vary according to trophic level and, in marine ecosystems, $\delta^{15}\text{N}$ values increase

by approximately 3‰ with each trophic level (Post 2002; Schoeninger and DeNiro 1984; Wada 1980). We argue that this innovative application of a well-established technique in archaeology provides a minimally invasive way to examine marine resource use in the past and is applicable at a variety of archaeological sites.

In this article, we present an overview of published nitrogen isotope values in the Arctic and Subarctic as well as new isotopic data from ethnoarchaeological soil samples collected from known herring processing areas and a historic semisubterranean structure at Tununak, a contemporary Yup'ik community located on Nelson Island in southwestern Alaska (Figs. 1, 2). First, we discuss nitrogen isotope analysis in soils, followed by a discussion of observed and expected nitrogen isotope values in arctic ecosystems. We then introduce our case study from the site of Tununak and the Yukon-Kuskokwim Delta of southwestern Alaska, followed by our field and laboratory methods

and results. We conclude with a discussion of the utility of nitrogen isotope analysis of archaeological soils to elucidate past subsistence behaviors.

NITROGEN ISOTOPE ANALYSIS OF ETHNOARCHAEOLOGICAL AND ARCHAEOLOGICAL SOILS

Since $\delta^{15}\text{N}$ values vary with trophic level, archaeologists have used nitrogen isotope values to investigate paleodiet in archaeological human remains (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984; Schoeninger et al. 1983; Walker and DeNiro 1986). Nitrogen isotopes of bone collagen (Commisso and Nelson 2010; Drucker and Bocherens 2004; Jay and Richards 2006), hair keratin (Fernández et al. 1999; Knudson et al. 2007; Macko et al. 1999), and tooth dentine (Balasse et al. 2001; Fuller et al. 2003; Wright and Schwarcz 1999) are widely used

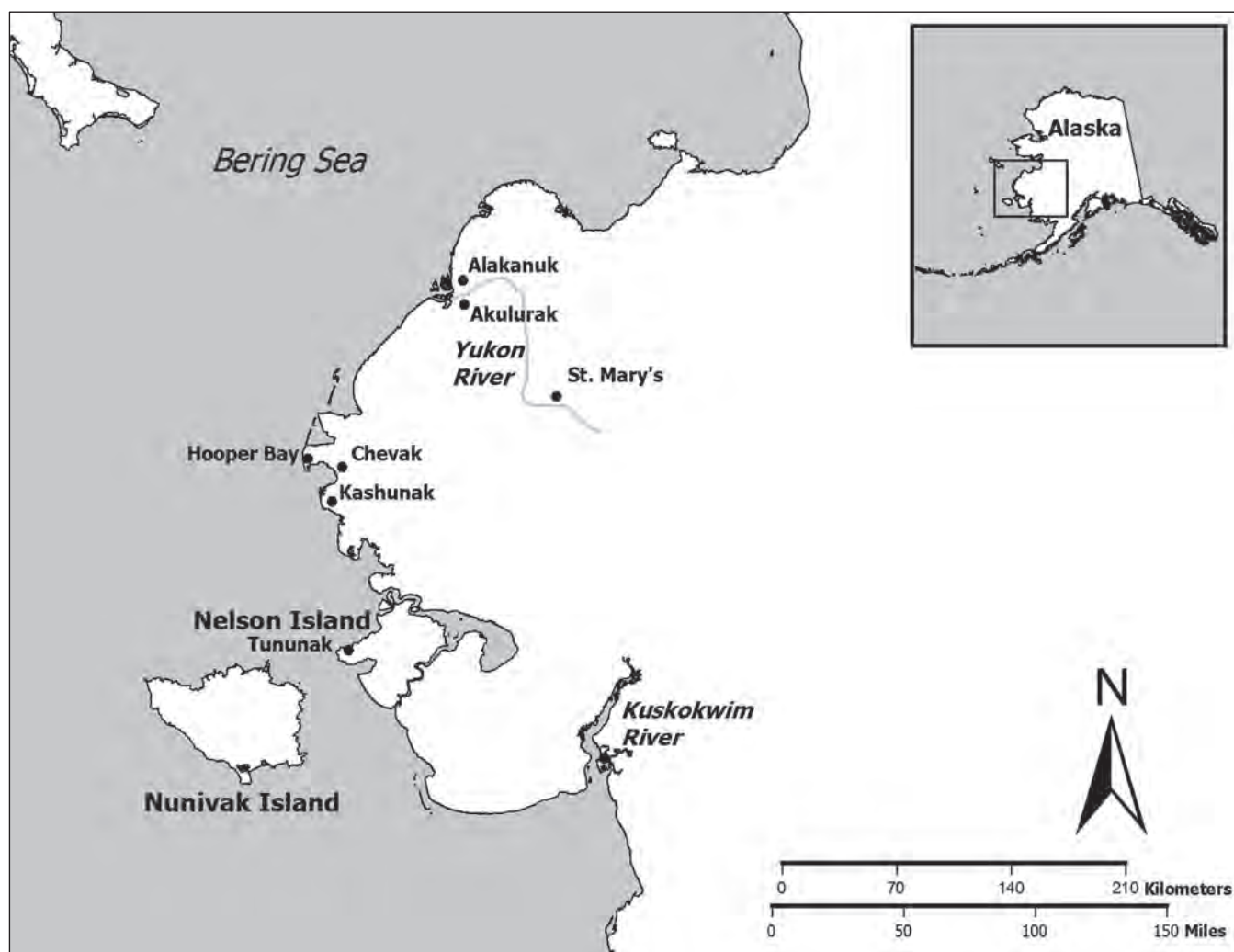


Figure 1. Location of the study site of Tununak in western Alaska.

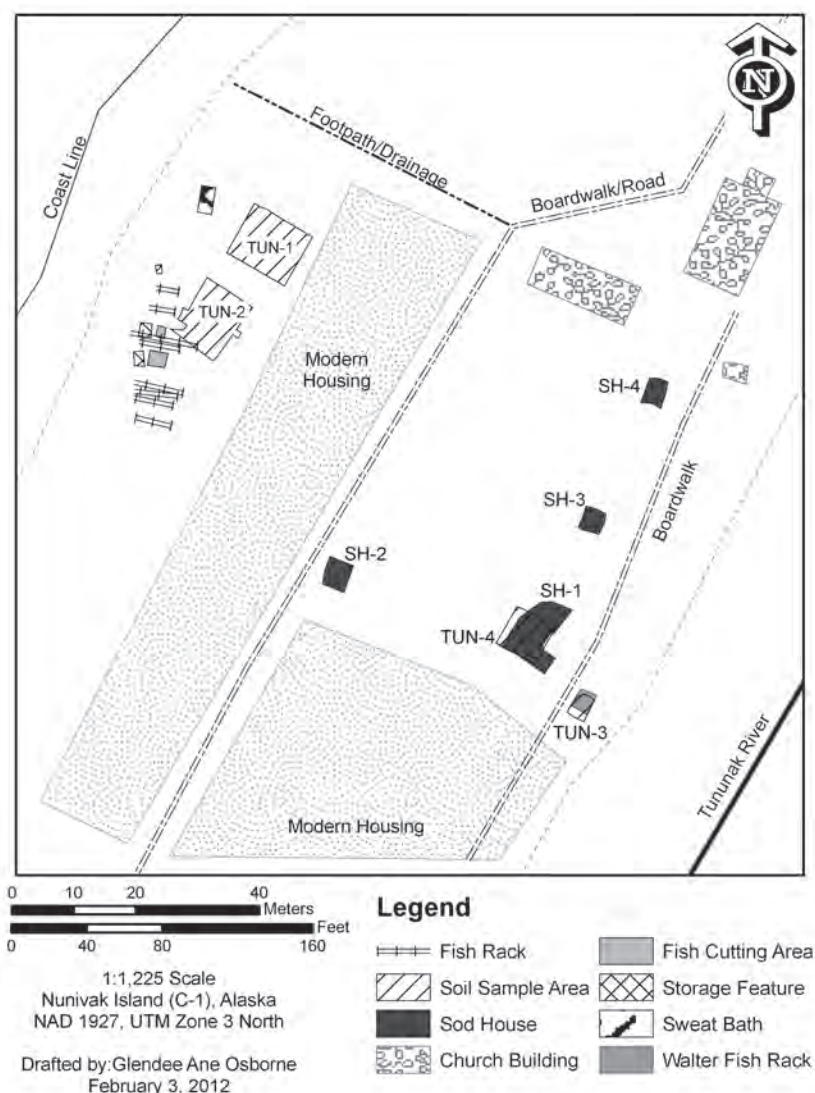


Figure 2. Site map of Tununak with location of the fish processing areas and semisubterranean dwelling.

to investigate paleodiet. In addition, the role of climatic effects, manuring, and trophic level differences continue to be investigated (Ambrose 1991; Ambrose and DeNiro 1987; Bogaard et al. 2007; Hedges and Reynard 2007).

The majority of these studies focused on the elucidation of paleodiet through light stable isotope analyses of bone collagen (see overviews in Katzenberg 2000; Katzenberg and Harrison 1997; Schoeninger and Moore 1992; Tykot 2006). However, archaeologists have recently applied nitrogen isotope analysis to ethnoarchaeological and archaeological soil samples. For example, analysis of ethnoarchaeological soil samples from Maasai sites in Kenya demonstrated that the soils in abandoned livestock enclosures were substantially enriched in ^{15}N (Shahack-Gross et al. 2008). Enrichment of ^{15}N in archaeologi-

cal soils can therefore be used to identify and better understand pastoralism in the archaeological record. Despite a number of studies using nitrogen isotope analyses of soils in other parts of the world, little work has been done in arctic and subarctic environments.

NITROGEN ISOTOPE ENRICHMENT AND MARINE RESOURCE USE: A NOVEL APPLICATION IN ETHNOARCHAEOLOGICAL AND ARCHAEOLOGICAL SOILS

There is a long history of research into the complex behavior of nitrogen in soils (see overviews in Cheng et al. 1964; Evans 2007; Hart and Myrold 1996; Hedin et al. 1998; Högborg 1997; Hübner 1986). Briefly, a simplified nitrogen cycle involves nitrogen fixation, in which microorganisms such as *Rhizobium* sp. remove nitrogen (N_2) from the air and convert nitrogen gas (N_2) to ammonia (NH_3). The ammonium ion (NH_4^+) can be converted into nitrite (NO_2^-) and nitrate (NO_3^-) through nitrification. The incorporation of ammonium (NH_4^+) or nitrate (NO_3^-) into living tissue is called assimilation or immobilization, while the degradation of organic matter and release of ammonium (NH_4^+) is called mineralization or ammonification. Finally, denitrification is the conversion of nitrate (NO_3^-) and nitrite (NO_2^-) to nitrogen gas (N_2) by anaerobic bacteria, some fungi, and aerobic bacteria.

At different stages of the nitrogen cycle, the two stable isotopes of nitrogen, ^{15}N and ^{14}N , are fractionated, resulting in different $\delta^{15}\text{N}$ values. In soil, $\delta^{15}\text{N}$ values are determined by the initial isotopic composition and subsequent fractionation during nitrogen inputs, transformations, and loss (see overviews in Evans 2007; Sharp 2007; Yoneyama 1996). Nitrogen inputs in soils include nitrogen fixation, atmospheric deposition, and fertilizers. Nitrogen transformations include mineralization. Finally, nitrogen loss in soils generally results from volatilization, nitrification, and denitrification (e.g., Bergstrom et al. 2002; Erskine et al. 1998). At each of these stages, isotopic fractionation effects can vary from $\delta^{15}\text{N}_{(\text{AIR})} = 0\text{--}3\text{‰}$ during nitrogen

fixation to $\delta^{15}\text{N}_{(\text{AIR})} = 20\text{‰}$ during nitrification (Evans 2007; Sharp 2007; Yoneyama 1996). While there can be very large changes in $\delta^{15}\text{N}$ values at different stages in the nitrogen cycle, the $\delta^{15}\text{N}$ value of soil total nitrogen is largely determined by the isotopic composition of stable nitrogen in the soil (Högberg 1997); this value is unlikely to change quickly and ensures that the $\delta^{15}\text{N}$ value of soil total nitrogen exhibits much less variability compared to the variability seen in marine ecosystems, as discussed below.

Therefore, we argue that the variability of nitrogen isotope values in soils that is based on soil functions and speciation will be much smaller than the variability based on the incorporation of marine-derived nitrogen into soils in a particular area. For example, when marine-derived nitrogen from salmon carcasses was incorporated into terrestrial soils, vegetation, and invertebrates in six different sites in British Columbia, there was statistically significant ^{15}N enrichment in the terrestrial ecosystem (Reimchen et al. 2002). In fact, there was a direct correlation between salmon spawning density and ^{15}N enrichment in the associated soils (Reimchen et al. 2002). For example, salmon carcass density was highest at Warn Bay Creek in British Columbia and nitrogen isotope values were highest in soil humus samples [mean $\delta^{15}\text{N}_{(\text{AIR})} = 1.5\text{‰} \pm 1.3\text{‰}$ (1σ , $n = 35$)], huckleberry (*Vaccinium parvifolium*) vegetation samples [mean $\delta^{15}\text{N}_{(\text{AIR})} = 1.6\text{‰} \pm 2.9\text{‰}$ (1σ , $n = 13$)], and salmonberry (*Rubus spectabilis*) vegetation samples [mean $\delta^{15}\text{N}_{(\text{AIR})} = 3.2\text{‰} \pm 2.5\text{‰}$ (1σ , $n = 18$)] (Reimchen et al. 2002). In comparison, nitrogen isotope values from Bulson River, where salmon were not present, were lower [soil humus sample mean $\delta^{15}\text{N}_{(\text{AIR})} = 0.9\text{‰} \pm 1.3\text{‰}$ (1σ , $n = 30$); huckleberry (*Vaccinium parvifolium*) vegetation sample mean $\delta^{15}\text{N}_{(\text{AIR})} = -0.9\text{‰} \pm 1.9\text{‰}$ (1σ , $n = 16$); and salmonberry (*Rubus spectabilis*) vegetation sample mean $\delta^{15}\text{N}_{(\text{AIR})} = -0.1\text{‰} \pm 2.5\text{‰}$ (1σ , $n = 15$)] (Reimchen et al. 2002). Similarly, marine-derived nitrogen from spawning salmon and seabirds also resulted in ^{15}N enrichment in Alaskan and Canadian ecosystems (Ben-David et al. 1998a, 1998b; Bilby et al. 1996; Finney et al. 2000; Griffiths et al. 2010; Hilderbrand et al. 1999; Holtham et al. 2004; Keatley et al. 2011; Krummel et al. 2009; Selbie et al. 2007), while the introduction of predators such as Arctic foxes (*Alopex lagopus*) reduced the sea bird population on fox-infested islands in the Aleutian archipelago, and therefore reduced the nitrogen isotope values found in soils (Croll et al. 2005; Maron et al. 2006).

However, we also note that the agricultural practice of manuring or soil microbial processes could result in elevated $\delta^{15}\text{N}$ values in soils. For example, manuring results in elevated $\delta^{15}\text{N}$ values in plants grown in these agricultural fields (Bogaard et al. 2007; Choi et al. 2002, 2003; Commisso and Nelson 2010; Koerner et al. 1999; Meharg et al. 2006), and in the bone collagen of individuals who consume those crops (Bogaard et al. 2007; Finucane 2007). We recommend using additional lines of evidence, including site location, to eliminate the possibility that intentional manuring resulted in elevated $\delta^{15}\text{N}$ values at a particular archaeological site.

Given the clear evidence for ^{15}N -enrichment from marine resources in terrestrial ecosystems in the ecological literature, we hypothesize that terrestrial soils from archaeological sites where marine resources were processed will exhibit higher $\delta^{15}\text{N}$ values than soils that do not contain marine-derived ^{15}N . Important questions, however, involve the residence time of marine-derived ^{15}N -enrichment in soils and the age of the archaeological sites that can be analyzed using this technique. Elevated $\delta^{15}\text{N}$ values have been identified in former agricultural sites (Bogaard et al. 2007; Choi et al. 2002, 2003; Commisso and Nelson 2010; Koerner et al. 1999; Meharg et al. 2006). For example, ^{15}N -enriched plants growing on abandoned medieval farms in Greenland demonstrate that enrichment is present at least 500 years after deposition (Commisso and Nelson 2006, 2007, 2008, 2010); ^{15}N enrichment in former agricultural lands have been identified 200 years after deposition in France (Koerner et al. 1999). Therefore, we hypothesize that this technique will be useful at archaeological sites, although we note that soil nitrogen turnover rates will vary and must be quantified for each study region. We now turn to a discussion of nitrogen isotope baseline values from our study region in order to generate expectations of marine-derived nitrogen in archaeological and ethnoarchaeological soils.

NITROGEN ISOTOPE VALUES IN THE ARCTIC: AN OVERVIEW

Trophic-level variability in $\delta^{15}\text{N}$ values has been well-established in a number of different ecosystems and, in general, $\delta^{15}\text{N}$ values increase by 3–4‰ for each successive trophic level (see overviews in Ambrose 1991; DeNiro and Epstein 1981; Kelly 2000; Koch 1998, 2007; Schoeninger 1985; Schoeninger and Moore 1992; Schwarcz and

Schoeninger 1991). However, there is also evidence that climatic variability, particularly aridity, and nutritional stress can also affect nitrogen isotope composition in vertebrates (Ambrose 1991; Fuller et al. 2004, 2005; Hatch et al. 2006; Mekota et al. 2006). Therefore, here we reconstruct nitrogen isotope values in different trophic levels in both marine and terrestrial ecosystems in the Arctic and Subarctic and use these values as our study baseline (Table 1, Fig. 3, Appendix 1).

In arctic and subarctic marine ecosystems, there are clear trophic level differences in $\delta^{15}\text{N}$ values (Table 1, Fig. 3, Appendix 1) (Michener and Kaufman 2007). While benthic algae exhibits a mean $\delta^{15}\text{N}$ value of $1.4\text{‰} \pm 2.0\text{‰}$ (Kline et al. 1990), primary consumers and animals that consumed a mixture of primary producers and primary consumers exhibit higher $\delta^{15}\text{N}$ values; these include anadromous fish such as salmon

(*Oncorhynchus* spp.), squid (*Berryteuthis magister* and *Gonatopsis borealis*), and walrus (*Odobenus rosmarus*). Largely secondary consumers, such as humpback whales (*Megaptera novaeangliae*), Pacific herring (*Clupea pallasii*), and Pacific cod (*Gadus macrocephalus*), exhibited higher $\delta^{15}\text{N}$ values than largely primary consumers. Finally, tertiary consumers in the marine ecosystem exhibit very high $\delta^{15}\text{N}$ values; these animals include Steller sea lions (*Eumetopias jubatus*), killer whales (*Orcinus orca*), and polar bears (*Ursus maritimus*).

However, we note that $\delta^{15}\text{N}$ values do vary within an organism, based on sample and tissue type (Ambrose 1991; DeNiro and Epstein 1981; Minagawa and Wada 1984). Therefore, we also present mean bone collagen $\delta^{15}\text{N}$ values to remove variability in sample type. There are clear trophic level differences in bone collagen samples from the arctic marine ecosystem. For example,

Table 1. Mean nitrogen isotope values and standard deviation (σ) of baseline samples from the Arctic listed in ascending order.

Species*	mean $\delta^{15}\text{N}$ (‰)	σ	References
Primary Consumers			
Zooplankton	10.6	1.7	Atwell et al. 1998; Hobson et al. 1997; Hoekstra et al. 2002; Kline 1997, 1999; Lee et al. 2005; Schell et al. 1998
Anadromous fish [Salmon (<i>Oncorhynchus</i> spp.) and Dolly varden trout (<i>Salvelinus malma</i>)]	11.1	2.1	Hoekstra et al. 2002; Kaeriyama et al. 2004; Kline et al. 1990; Misarti 2007; Satterfield and Finney 2002; Uchiyama et al. 2008
Crustaceans*	11.9	1.4	Dunton et al. 1989; Kline 1999
Squid (<i>Berryteuthis magister</i> and <i>Gonatopsis borealis</i>)	11.7	2.4	Hobson et al. 1997; Kurle and Worthy 2001
Walrus (<i>Odobenus rosmarus</i>)	12.9	0.5	Atwell et al. 1998; Dehn et al. 2006; Hobson and Welch 1992
Secondary Consumers			
Humpback whale (<i>Megaptera novaeangliae</i>)	13.0	1.0	Witteveen et al. 2009
Pacific herring (<i>Clupea pallasii</i>)	13.7	1.1	Kline 1999; Kurle and Worthy 2001
Sea birds*	14.7	1.7	Atwell et al. 1998; Hobson et al. 1994, 2004a, 2004b; Hobson and Montevecchi 1991
Sea otter (<i>Enhydra lutris</i>)	15.3	2.1	Worthy 2008
Harbor porpoise (<i>Phocoena phocoena</i>)	15.6	0.4	Toperoff 2002
Pacific cod (<i>Gadus macrocephalus</i>)	16.1	2.0	Dunton et al. 1989; Hobson et al. 1997; Misarti 2007
Tertiary Consumers			
Northern fur seal (<i>Callorhinus ursinus</i>)	16.9	1.1	Burton and Koch 1999; Hirons 2001; Hobson et al. 1997; Kurle and Worthy 2001, 2002; Newsome et al. 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	17.8	0.9	Hirons 2001; Hobson et al. 1997, 2004a, 2004b; Kurle and Gudmundson 2007; Misarti 2007
Killer whale (<i>Orcinus orca</i>)	17.9	1.6	Herman et al. 2005; Worthy 2008
Polar bear (<i>Ursus maritimus</i>)	20.4	0.8	Atwell et al. 1998; Dehn et al. 2006; Hobson and Welch 1992

* See individual species listed in Appendix 1.

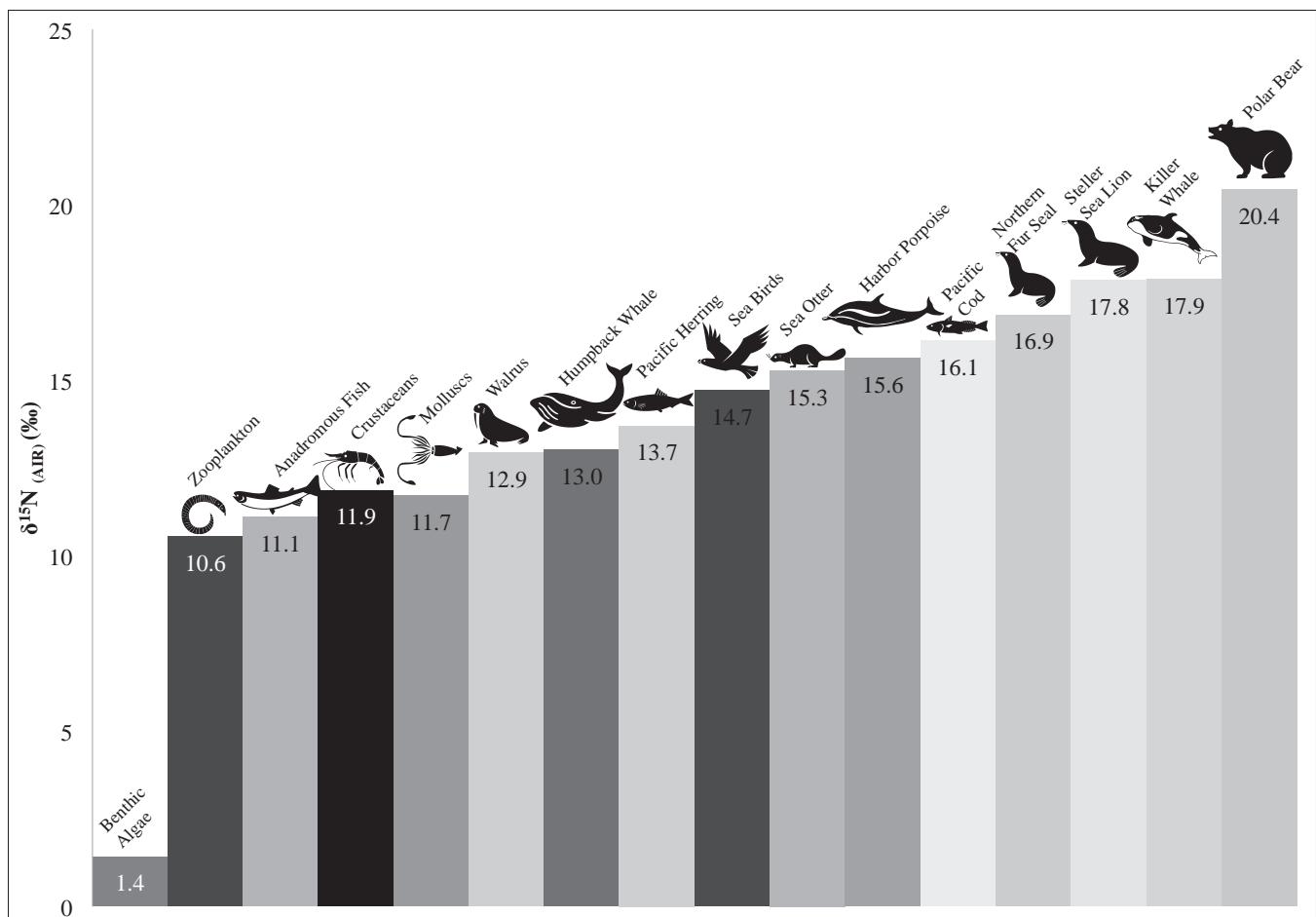


Figure 3. Mean nitrogen isotope values of baseline samples from the Arctic (mean data in Table 1 from Atwell et al. 1998; Burton and Koch 1999; Dehn et al. 2006; Dunton et al. 1989; Herman et al. 2005; Hirons 2001; Hobson et al. 1994, 1997; Hobson, Bowen et al. 2004; Hobson and Montevecchi 1991; Hobson, Sinclair, et al. 2004; Hobson and Welch 1992; Hoekstra et al. 2002; Kaeriyama et al. 2004; Kline 1997, 1999; Kline et al. 1990, 1993; Kurle and Gudmundson 2007; Kurle and Worthy 2001, 2002; Lee et al. 2005; Misarti 2007; Newsome et al. 2007; Satterfield and Finney 2002; Schell 2001; Schell et al. 1998, Toperoff 2002; Uchiyama et al. 2008; Witteveen et al. 2009; Worthy 2008).

when only bone collagen samples are included, mean $\delta^{15}\text{N}$ values are as follows:

- anadromous fish (*Oncorhynchus* spp.) $10.5\text{‰} \pm 1.6\text{‰}$
Misarti 2007
- Tufted puffin (*Fratercula cirrhata*) $16.1\text{‰} \pm 2.3\text{‰}$
Hobson and Montevecchi 1991;
Hobson et al. 1994
- Pacific cod (*Gadus macrocephalus*) $16.4\text{‰} \pm 0.4\text{‰}$
Misarti 2007
- Northern fur seals (*Callorhinus ursinus*) $17.1\text{‰} \pm 1.5\text{‰}$
Burton and Koch 1999; Hirons 2001;
Misarti 2007; Newsome et al. 2007
- Steller sea lions (*Eumetopias jubatus*) $18.0\text{‰} \pm 0.6\text{‰}$
Hirons 2001; Hobson, Bowen et al.
2004; Misarti 2007

In arctic and subarctic terrestrial ecosystems, nitrogen isotope values in O and B horizons of forest soils and sediment cores from lakes have a mean $\delta^{15}\text{N}$ of $1.3\text{‰} \pm 1.8\text{‰}$ (Hobbie et al. 1998; 2000; Misarti 2007). Terrestrial vegetation from areas without piscivorous predator activity exhibited a mean $\delta^{15}\text{N}$ of $1.1\text{‰} \pm 3.6\text{‰}$ in Chichagof Island (Ben-David et al. 1998b), while small mammals from areas away from ^{15}N -enriched vegetation ranged from values from -0.1‰ to 4.0‰ (Ben-David et al. 1998b). Arctic fox (*Alopex lagopus*) exhibited a mean value of $10.3\text{‰} \pm 1.4\text{‰}$ (Dehn et al. 2006). As previously discussed, we note that terrestrial ecosystems can exhibit nonanthropogenic ^{15}N enrichment (Ben-David et al. 1998a, 1998b; Bilby et al. 1996; Hilderbrand et al. 1999; Reimchen et al. 2002). In addition, nitrogen cycles

in arctic terrestrial ecosystems are very complex (Binkley et al. 1985; Blackmer and Bremner 1977; Chapin et al. 1988; Chapin et al. 1993; Chapin and Shaver 1981; Hu et al. 2001; Kaye et al. 2003; Rhoades et al. 2001). However, we hypothesize that the anthropogenic inputs from processing marine resources will result in ^{15}N enrichment in soils that is significantly greater than the variability in soil values discussed here. Finally, we note that climatic variability and changes in animal behavior and prey species availability over time can result in $\delta^{15}\text{N}$ variability (Misarti 2007; Misarti et al. 2009); however, these temporal changes are smaller than the expected ^{15}N enrichment in anthropogenically altered soils.

CASE STUDY: NITROGEN ISOTOPE ANALYSIS OF ETHNOARCHAEOLOGICAL SOILS ON NELSON ISLAND

SUBSISTENCE PRACTICES AT THE YUP'IK COMMUNITY OF TUNUNAK

Nelson Island lies just off the mainland coast of southwestern Alaska and is geologically part of the Yukon-Kuskokwim Delta (Fig. 1). The Yup'ik community of Tununak, on the northwestern coast of the island, has approximately 300 inhabitants. Its location on the Bering Sea coast enables residents to take advantage of spring, summer, and fall resources (Barker 1993; Frink 2009), since they depend on subsistence foods for a large part of their diet. Residents still harvest large numbers of migrating waterfowl such as Canada goose (*Branta canadensis*) and collect flora from the land including berries (*Rubus* spp.) (Ager and Ager 1980).

Although terrestrial resources are utilized at Tununak, fish is arguably the most important subsistence food for coastal Yup'ik people (e.g., Nash et al. 2009, 2012; O'Brien et al. 2009; Wilkinson et al. 2007). Herring (*Clupea* spp.) is particularly significant, and Tununak is located near herring spawning grounds. Every year, men, as the primary subsistence harvesters, fish for herring while the women of Tununak, the primary subsistence producers, spend weeks processing and drying the fish for the winter months (Figs. 2, 3) (Barker 1993; Fienup-Riordan 1983, 1986; Frink and Knudson 2010; Frink 2002, 2007, 2009; Frink et al. 2003; Pete et al. 1987). Although herring is vital to the inhabitants of Tununak, Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*Oncorhynchus kisutch*), Pacific halibut (*Hippoglossus*

stenolepis), and Pacific cod (*Gadus macrocephalus*) are also important marine resources (Pete et al. 1987). People also rely on several sea mammal taxa, including five species of seal [ringed (*Pusa hispida*), harbor (*Phoca vitulina*), spotted (*Phoca largha*), ribbon (*Histiophoca fasciata*), and bearded (*Erignathus barbatus*)], as well as beluga whale (*Delphinapterus leucas*). As discussed in more detail elsewhere (Frink and Knudson 2010; Knudson and Frink 2010a), as fish and other marine products are processed and dried at Tununak, discarded flesh and whole fish are incorporated into the soils of the processing and storage areas, creating anthropogenically altered soils.

PHYSICAL ENVIRONMENT AND SOILS AT TUNUNAK

Most of the Yukon-Kuskokwim Delta is composed of Quaternary sands and silts, underlain by Cenozoic sedimentary rocks; delta soils are generally mapped as Histis Pergelic Cryaquepts and Pergelic Cryofibrists (Gough et al. 1988; Lyle et al. 1982; MacManus et al. 1974). Because of the large numbers of lakes and rivers and a discontinuous permafrost layer, delta soils are poorly drained and minimally weathered. The physical characteristics of the soils collected at Tununak are described in detail in the following sections.

FIELD METHODS: SAMPLE COLLECTION AT TUNUNAK

In May 2007, we collected ethnoarchaeological soil samples at Tununak from current fish processing areas during herring procurement and processing¹ (Figs. 4, 5). In these areas, approximately 10 grams of soil (wet weight) were collected in a 1 x 1 meter grid; this point sampling strategy was designed to assess the isotopic variability (Entwistle et al. 2000; Haslam and Tibbett 2004; Wells 2010) and to compare the isotopic signatures of the soils in the fish processing areas and drying racks with the isotopic signatures in the soils from unused spaces between the racks and along the edges of the processing areas.

We also collected ethnoarchaeological soil samples from an abandoned semisubterranean structure in Tununak in order to understand the isotopic signatures of areas where marine products were stored and processed, although less intensively than at the fish processing sites² (Fig. 6). The construction, use and attributes of the semisubterranean structure are discussed in detail elsewhere (Knudson and Frink 2010b). Within and

outside of the turf walls of the structure, a point sampling strategy was used (Entwistle et al. 2000; Haslam and Tibbett 2004). Samples were collected in a 1 x 1 meter grid. At each sampling location, a galvanized steel soil sampler was used to take soil cores and to collect samples at depths of five centimeters at each point (Caldwell et al. 2005; Feek et al. 2006). Therefore, at each point on our one-meter grid within and around

the semisubterranean structure, we collected samples from the surface soil, including roof fall in some areas, from the house floors, and from underneath the floors. Interviews with former inhabitants of the sod house that was sampled allowed us to reconstruct the life history of the structure, including length of occupation, time of abandonment, and identification of activity areas in and around the house (Knudson and Frink 2010b).



Figure 4. Herring braids on racks at Tununak, Nelson Island, Alaska. Photo by Kelly Knudson.

FISH PROCESSING AREA 1

123	122	121	120	119	118	117	116	115	114	113	112
100	101	102	103	104	105	106	107	108	109	110	111
099	098	097	096	095	094	093	092	091	090	089	088
078	079	080	081	082	083	084	085	086	087	088	089
077	076	075	074	073	072	071	070	069	068	067	066
054	055	056	057	058	059	069	061	062	063	064	065
053	052	051	050	049	048	047	046	045	044	043	042
030	031	032	033	034	035	036	037	038	039	049	041
029	028	027	026	025	024	023	022	021	020	019	018
006	007	008	009	010	011	012	013	014	015	016	017
001	002	003	004	005							

FISH PROCESSING AREA 2

124	125	126	127	128	129	130	131	132	133		
139	138	137	136					135	134		
140	141	142						143	144		
147								146	145		
148	149	150	151	152	153	154	155	156	157		
167	166	165	164	163	162	161	160	159	158		
168	169	170	171	172	173	174	175	176	177		
187	186	185	184	183	182	181	180	179	178		
188	189	190	191	192	193	194	195	196	197		
		205	204	203	202	201	200	199	198		
206	207	208	209	210	211	212	213	214	215		

FISH PROCESSING AREA 3

280	279	278		
275	276	277	271	
274	273	272	281	270
269	268	267	263	
266	265	264	262	

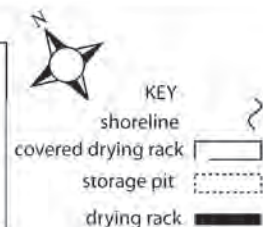


Figure 5. Fish processing areas sampled at Tununak with sample locations identified. Not to scale.

SOD HOUSE 1

317-321	322-326	397-401	402-406	477-481	482-486	557-561	562-566
312-316	327-329	392-394	407-411	472-476	487-491	552-556	567-571
307-311	332-336	387-391	412-416	467-471	492-496	547-551	572-576
302-306	337-341	382-386	417-421	462-466	497-501	542-546	577-581
297-301	342-346	377-381	422-426	457-461	502-506	537-541	582-586
292-296	347-351	372-376	427-431	452-456	507-511	532-536	587-591
287-291	352-356	367-371	432-436	447-451	512-516	527-531	592-596
282-286	357-361	362-366	437-441	442-446	517-521	522-526	597-601



Figure 6. Abandoned semisubterranean dwelling sampled at Tununak with sample locations identified. Not to scale.

All soil samples were collected to ensure that variability in $\delta^{15}\text{N}$ values in the Tununak soils was due to the incorporation of marine products into the soils, rather than non-anthropogenic soil processes. More specifically, denitrification can have very large fractionation effects (Sharp 2007). Since denitrification often occurs in poorly-aerated, saturated soils as well as in deeper layers of soil, samples were collected from areas that were similarly saturated throughout the year. With the exception of the semi-subterranean structure samples, which were collected at a number of different depths and will be discussed in detail below, all offsite and fish processing area samples were collected at the same depth to control for depth-related variability in $\delta^{15}\text{N}$ values.

In addition to the fish processing area and semi-subterranean structure samples, we collected soil samples from three offsite areas to examine the isotopic signatures of soils not affected by anthropogenic processes³ (Fig. 7). Offsite soil samples were collected using a nested sampling regime to examine the spatial variability in the soils with fewer samples (Andronikov et al. 2000; Lark 2005; Youden and Mehlich 1937). Samples were also collected from a fourth offsite sampling area to examine the isotopic effects of bird waste and fecal material on soil. Finally, baseline samples from both the marine and terrestrial ecosystems were collected in October of 2009 and July of 2010. Vegetation, shell, and fish samples were collected opportunistically and are listed in Table 2; all vertebrate samples were collected from carcasses with the permission of the subsistence hunters who obtained the fish.

LABORATORY METHODS:

SAMPLE ANALYSIS AT ARIZONA STATE UNIVERSITY

All samples were prepared in the Archaeological Chemistry Laboratory at Arizona State University. Each soil or plant sample was first dried at 60°C for forty-eight hours, pulverized with a Coors porcelain mortar and pestle and screened with a 2 mm screen to remove all particles larger than sand-sized, and then pulverized using a ball mill (Choi et al. 2002; Gebauer and Schulze 1991; Shahack-Gross et al. 2008). Bone samples were chemically cleaned using 95% and 100% ethanol ($\text{C}_2\text{H}_5\text{OH}$) and acetone ($(\text{CH}_3)_2\text{CO}$) and demineralized using 0.25 M hydrochloric acid (HCl). Modern bone samples were then treated with a 1:2:0.8 solution of chloroform (CHCl_3), methanol (CH_3OH), and water (H_2O) to remove any

lipids present and then treated with 0.125 M sodium hydroxide (NaOH) to remove any humic acids present before solubilizing and freeze-drying the samples (Ambrose 1990; Jørkov et al. 2007).

Samples were analyzed at the W. M. Keck Foundation Laboratory for Environmental Biogeochemistry using a Delta Plus Advantage Isotope Ratio Mass Spectrometer (IRMS) coupled with a Costech Elemental Analyzer (EA). Accuracy and precision were determined using the external and internal standards of NIST-1646 (estuarine sediment), USGS SDO-1 (Devonian Ohio Shale), glycine, acetanilide, and ACL-1119 (TUN-0250). When possible, samples were analyzed in triplicate on the same day and during subsequent sample runs (Pye et al. 2006). Maximum standard error on soil, plant and bone collagen sample replicates was $\delta^{15}\text{N}_{(\text{AIR})} = 0.3\text{‰}$. Nitrogen isotope ratios are reported relative to the AIR (atmospheric nitrogen) standard and are expressed in parts per mil (‰) using the following formula: $\delta^{15}\text{N} = ((^{15}\text{N}/^{14}\text{N}_{\text{sample}})/(^{15}\text{N}/^{14}\text{N}_{\text{standard}})) - 1 \times 1,000$ (Mariotti 1983).

RESULTS OF THE CASE STUDY

Terrestrial plants collected from Tununak exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.7\text{‰} \pm 0.5\text{‰}$ (1σ , $n = 3$) (Table 2). In contrast, marine plants collected from Tununak exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 22.1\text{‰} \pm 2.6\text{‰}$ (1σ , $n = 9$). All fish samples exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.6\text{‰} \pm 0.9\text{‰}$ (1σ , $n = 13$); more specifically, anadromous fish exhibit a range of $\delta^{15}\text{N}_{(\text{AIR})} = 10.8\text{‰}$ to $\delta^{15}\text{N}_{(\text{AIR})} = 12.4\text{‰}$ and marine fish exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.5\text{‰} \pm 1.0\text{‰}$ (1σ , $n = 11$). These nitrogen isotope values are similar to expected values based on light stable nitrogen isotope data from published sources, as previously discussed (Fig. 3, Appendix 1).

Nitrogen isotope data from all ethnoarchaeological samples collected at Tununak are presented in Tables 3 and 4. Nitrogen isotope values from the offsite areas exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.2\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 35$). The fish processing areas exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.4\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 49$). The nitrogen isotope values from all samples collected from the sod house exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 6.8\text{‰} \pm 0.2\text{‰}$ (1σ , $n = 105$) (Table 4).

DISCUSSION OF NITROGEN ISOTOPE VALUES IN ETHNOARCHAEOLOGICAL SOILS FROM TUNUNAK

An examination of the nitrogen isotope values from the offsite areas [mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.2\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 35$)]

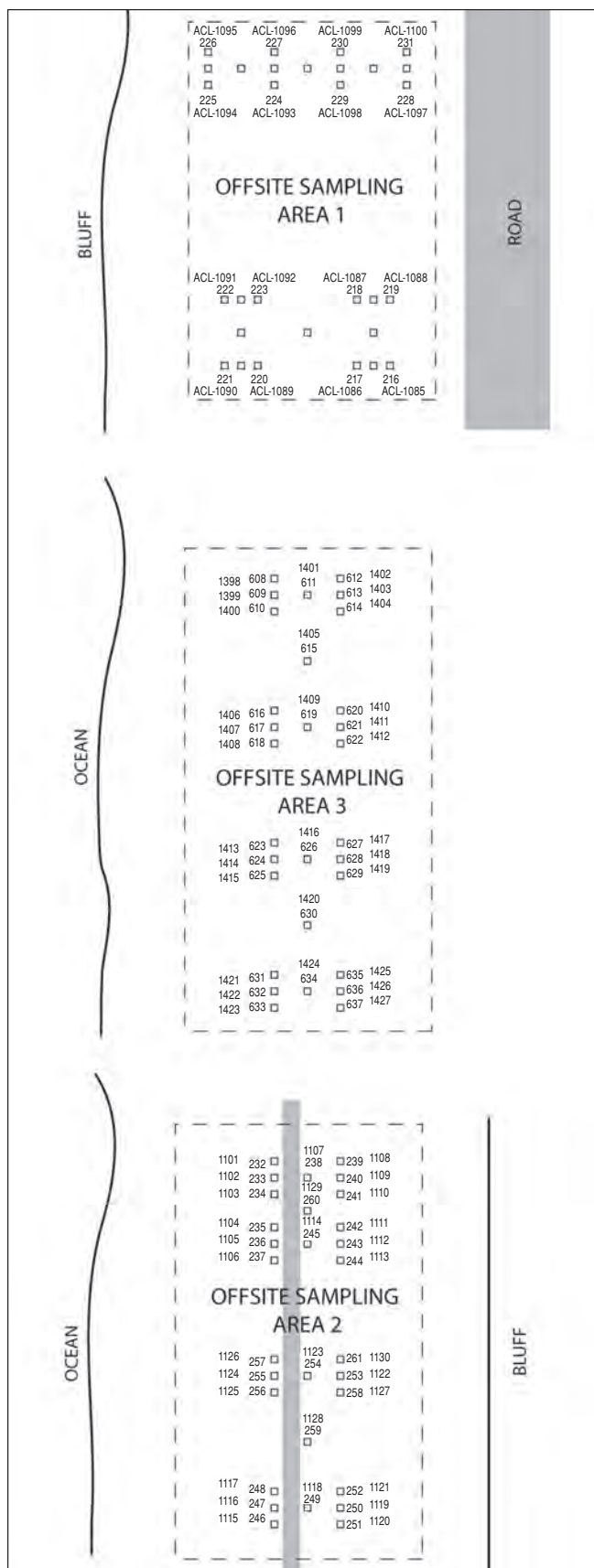


Figure 7. Offsite areas sampled at Tununak with sample locations identified. Not to scale.

and the fish processing areas [$\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 13.4\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 49$)] shows that the fish processing area soil are enriched in ^{15}N (Table 4). The difference in $\delta^{15}\text{N}_{(\text{AIR})}$ values between fish processing area samples and offsite area samples is statistically significant ($t = 19.5$, $df = 82$, $p < 0.001$). We interpret these data as reflecting the incorporation of marine-derived nitrogen from fish and marine mammals into the soils in the fish processing areas.

The nitrogen isotope values from the offsite areas [$\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 2.2\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 35$)] and all samples collected from the sod house [$\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 6.8\text{‰} \pm 0.2\text{‰}$ (1σ , $n = 105$)] are also distinct. The difference between all sod house samples and the offsite samples is also statistically significant ($t = 11.3$, $df = 138$, $p < 0.001$). Although processing marine products was less intensive in the semisubterranean structures compared to the fish processing areas, the sod house soils are enriched in ^{15}N , although less enriched than the fish processing soils. We interpret these data as indicating the incorporation of marine-derived nitrogen from fish and marine mammals into the floors of the sod house during processing, storing, consuming, and/or discarding marine products in and around the semisubterranean structures.

The enrichment in ^{15}N varies by soil depth, as demonstrated by soil samples collected at different depths at and below the hypothesized floor surface. The sod house soil samples were obtained from twenty-six different sampling locations within the house with different depths collected at the surface as well as every five centimeters below the surface. Out of the twenty-six sampling locations, eleven had soil samples from five depths, eleven had samples from four depths, one had samples from three depths, and three had a surface soil sample. Soils collected from the surface of the sod house floor exhibited $\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 8.7\text{‰} \pm 1.7\text{‰}$ (1σ , $n = 26$). Soils collected below the surface exhibited the following nitrogen isotope values: $\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 6.4\text{‰} \pm 1.4\text{‰}$ (5 cm below surface, 1σ , $n = 23$); $\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 5.9\text{‰} \pm 1.6\text{‰}$ (10 cm below surface, 1σ , $n = 23$); $\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 6.0\text{‰} \pm 1.8\text{‰}$ (15 cm below surface, 1σ , $n = 22$); and $\text{mean } \delta^{15}\text{N}_{(\text{AIR})} = 6.4\text{‰} \pm 1.7\text{‰}$ (20 cm below surface, 1σ , $n = 11$).

However, the variability of $\delta^{15}\text{N}_{(\text{AIR})}$ values by depth does not follow the pattern one would expect if it was due solely to soil formation processes. In general and across many different ecosystems, soil $\delta^{15}\text{N}_{(\text{AIR})}$ values increase with soil depth due to fractionation during mineralization, nitrification and loss of nitrogen gas (N_2)

Table 2. Nitrogen isotope data from all baseline samples collected from Nelson Island. Fish samples were collected opportunistically from carcasses obtained by subsistence hunters.

Laboratory Number	Field Sample Number	Species	Sample Type	Percentage of N in sample by weight	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)
ACL-2702	TUN-0663	cf. <i>Halosaccion</i> spp.	Sea sac (pod)	8.6	20.9
ACL-2706	TUN-0667	cf. <i>Halosaccion</i> spp.	Sea sac (pod)	14.5	20.0
ACL-2712	TUN-0673	cf. <i>Halosaccion</i> spp.	Sea sac (pod)	13.9	20.6
ACL-2713	TUN-0674	cf. <i>Codium fragile</i> spp.	Seaweed (blades)	5.2	24.5
ACL-2720	TUN-0679	<i>Plantago maritima</i>	Goose-tongue (rosette)	7.2	19.6
ACL-2723	TUN-0682	cf. <i>Callophyllis</i> spp.	Seaweed (blades)	4.5	18.6
ACL-2724	TUN-0683	cf. <i>Codium fragile</i> spp.	Seaweed (blades)	3.3	25.3
ACL-2728	TUN-0686	cf. <i>Codium fragile</i> spp.	Seaweed (blades)	4.4	25.6
ACL-2761	TUN-0690	unidentified plant	unidentified plant	3.2	23.4
ACL-2700	TUN-0661	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	14.4	19.4
ACL-2701	TUN-0662	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	14.2	19.1
ACL-2722	TUN-0681	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	13.3	20.3
ACL-2715	TUN-0675	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	14.3	18.9
ACL-2721	TUN-0680	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	12.1	18.7
ACL-2936	TUN-0715	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	12.9	18.6
ACL-2940	TUN-0719	<i>Hippoglossus stenolepis</i>	Pacific halibut bone collagen	12.1	18.5
ACL-2703	TUN-0664	unidentified fish bone	unidentified fish bone collagen	13.5	14.6
ACL-2930	TUN-0709	<i>Anarrhichthys ocellatus</i>	Wolf eel bone collagen	13.3	19.7
ACL-2949	TUN-0721	<i>Prosopium cylindraceum</i>	Whitefish bone collagen	15.1	15.7
ACL-2950	TUN-0722	<i>Paralichthys</i> sp.	Flounder bone collagen	12.8	14.6
ACL-2920	TUN-0699	cf. <i>Oncorhynchus keta</i>	Chum salmon bone collagen	14.1	10.8
ACL-2717	TUN-0677	<i>Oncorhynchus keta</i>	Chum salmon bone collagen	14.2	12.4
ACL-2688	TUN-0649	<i>Calamagrostis canadensis</i>	Bluejoint grass (stalk and glumes)	2.1	6.2
ACL-2730	TUN-0688	<i>Eriophorum angustifolium</i>	Cottongrass (stalk and flowers)	2.9	9.6
ACL-2731	TUN-0689	unidentified plant	unidentified plant	3.2	8.8

(Evans 2007; Fry 1991; Högberg 1997; Natelhoffer and Fry 1988). Therefore, since some of the highest $\delta^{15}\text{N}_{(\text{AIR})}$ values in the semisubterranean structure soils are from the first 10 cm of soil beneath the surface, we argue that this enrichment is at least partially due to ^{15}N enrichment from anthropogenic activities, such as processing and storing marine products.

CONCLUSIONS

In conclusion, we have presented an overview of published nitrogen isotope values in the Arctic and Subarctic. These data demonstrate the trophic level variability in these ecosystems. We believe that this variability indicates that the

Arctic, in particular, is an excellent region in which to use nitrogen isotope analysis to examine marine resource consumption, particularly in ethnoarchaeological and archaeological soils.

We have also presented new light stable isotope data from arctic baseline samples as well as ethnoarchaeological soil samples from known fish processing areas and a historic semisubterranean house. While terrestrial plants collected from Tununak exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.7\text{‰} \pm 0.5\text{‰}$ (1σ , $n = 3$), marine plants collected from Tununak exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 22.1\text{‰} \pm 2.6\text{‰}$ (1σ , $n = 9$). Anadromous fish exhibit a range of $\delta^{15}\text{N}_{(\text{AIR})} = 10.8\text{‰}$ to $\delta^{15}\text{N}_{(\text{AIR})} = 12.4\text{‰}$ and marine fish exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.5\text{‰} \pm 1.0\text{‰}$ (1σ , $n = 11$). Soils in offsite areas exhibited

Table 3. Nitrogen isotope data from all ethnoarchaeological samples collected from Nelson Island.

Laboratory Number	Field Sample Number	Percentage of N in sample by weight	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)	Sample Origin
Offsite Areas				
Offsite Area 1				
ACL-1085	TUN-0216	1.2	2.9	
ACL-1086	TUN-0217	1.3	-0.5	
ACL-1087	TUN-0218	1.1	2.7	
ACL-1090	TUN-0221	1.0	0.0	
ACL-1091	TUN-0222	0.9	0.8	
ACL-1095	TUN-0226	0.5	0.2	
ACL-1096	TUN-0227	0.7	-0.6	
ACL-1097	TUN-0228	0.8	-0.5	
Offsite Area 2				
ACL-1103	TUN-0234	0.5	2.8	
ACL-1108	TUN-0239	0.3	3.6	
ACL-1109	TUN-0240	0.3	4.0	
ACL-1112	TUN-0243	0.2	3.4	
ACL-1113	TUN-0244	0.3	3.7	
ACL-1118	TUN-0249	0.8	2.4	
ACL-1121	TUN-0252	0.3	1.6	
ACL-1127	TUN-0258	0.2	3.8	
ACL-1129	TUN-0260	0.5	2.9	
ACL-1130	TUN-0261	0.2	4.4	
Offsite Area 3				
ACL-1399	TUN-0609	0.3	13.7	
ACL-1400	TUN-0610	0.1	2.1	
ACL-1401	TUN-0611	0.0	2.5	
ACL-1405	TUN-0615	0.2	2.0	
ACL-1407	TUN-0617	0.1	1.5	
ACL-1408	TUN-0618	0.2	1.7	
ACL-1409	TUN-0619	0.1	1.9	
ACL-1411	TUN-0621	0.1	2.1	
ACL-1412	TUN-0622	0.3	1.0	
ACL-1414	TUN-0624	0.1	0.8	
ACL-1415	TUN-0625	0.0	1.2	
ACL-1417	TUN-0627	0.4	0.7	
ACL-1418	TUN-0628	0.3	1.7	
ACL-1420	TUN-0630	0.1	1.4	
ACL-1421	TUN-0631	0.3	2.0	
ACL-1423	TUN-0633	0.1	1.4	
ACL-1426	TUN-0636	0.2	1.1	
Fish Processing Area 1				
ACL-0886	TUN-0017	0.2	12.2	peripheral
ACL-0892	TUN-0023	0.2	14.2	rack
ACL-0894	TUN-0025	0.2	16.3	rack
ACL-0904	TUN-0035	0.1	11.3	rack
ACL-0907	TUN-0038	0.1	13.3	rack
ACL-0927	TUN-0058	0.2	17.2	rack
ACL-0928	TUN-0059	0.1	14.5	rack
ACL-0930	TUN-0061	0.1	13.1	rack
ACL-0936	TUN-0067	0.5	14.3	rack
ACL-0939	TUN-0070	0.2	13.2	rack
ACL-0942	TUN-0073	0.1	11.3	rack
ACL-0950	TUN-0081	0.1	12.0	near storage pit
ACL-0951	TUN-0082	0.1	15.5	rack
ACL-0965	TUN-0096	0.3	16.0	rack
ACL-0974	TUN-0105	0.1	14.0	peripheral, near storage pit

Table 3. (continued)

Laboratory Number	Field Sample Number	Percentage of N in sample by weight	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)	Sample Origin
ACL-0980	TUN-0111	0.7	12.9	peripheral
ACL-0982	TUN-0113	1.1	14.6	peripheral
ACL-0983	TUN-0114	0.2	13.2	peripheral
ACL-0988	TUN-0119	0.1	12.6	peripheral
ACL-0991	TUN-0122	0.0	7.2	peripheral, "walk area"
Fish Processing Area 2				
ACL-0941	TUN-0072	0.1	11.3	rack
ACL-0994	TUN-0125	0.2	14.0	rack
ACL-0999	TUN-0130	0.2	14.3	rack
ACL-1001	TUN-0132	0.5	16.5	rack
ACL-1005	TUN-0136	0.5	14.5	rack
ACL-1008	TUN-0139	0.1	12.5	rack
ACL-1011	TUN-0142	0.2	14.7	rack
ACL-1017	TUN-0148	0.1	14.3	peripheral
ACL-1019	TUN-0150	0.1	19.5	rack
ACL-1021	TUN-0152	0.2	13.4	peripheral, near tent
ACL-1022	TUN-0153	0.2	10.8	peripheral, near tent
ACL-1024	TUN-0155	0.1	11.1	peripheral, near tent
ACL-1047	TUN-0178	0.4	15.3	rack
ACL-1049	TUN-0180	0.3	14.3	rack
ACL-1052	TUN-0183	0.2	14.4	rack
ACL-1054	TUN-0185	0.2	15.7	rack
ACL-1060	TUN-0191	0.5	17.5	rack
ACL-1062	TUN-0193	0.3	11.3	rack
ACL-1065	TUN-0196	0.3	14.5	rack
ACL-1070	TUN-0201	0.3	15.9	rack
ACL-1071	TUN-0202	0.3	16.5	rack
Fish Processing Area 3				
ACL-1132	TUN-0263	0.2	11.1	peripheral
ACL-1134	TUN-0265	0.3	12.4	outside covered rack
ACL-1135	TUN-0266	0.4	10.4	peripheral, near doorway
ACL-1142	TUN-0273	0.5	11.8	covered rack
ACL-1143	TUN-0274	0.1	2.9	covered rack near door
ACL-1144	TUN-0275	0.4	9.1	covered rack near door
ACL-1147	TUN-0278	0.4	11.5	covered rack
ACL-1149	TUN-0280	0.2	15.1	covered rack
Sod House				
ACL-1151	TUN-0282	0.3	11.8	
ACL-1152	TUN-0283	0.4	8.8	
ACL-1153	TUN-0284	0.2	7.2	
ACL-1154	TUN-0285	0.1	6.5	
ACL-1155	TUN-0286	0.1	5.6	
ACL-1161	TUN-0292	0.3	7.0	
ACL-1162	TUN-0293	0.1	6.8	
ACL-1163	TUN-0294	0.1	7.2	
ACL-1164	TUN-0295	0.2	6.5	
ACL-1165	TUN-0296	0.1	6.5	
ACL-1168	TUN-0302	0.3	9.7	
ACL-1169	TUN-0303	0.4	10.0	
ACL-1170	TUN-0304	0.1	9.8	
ACL-1171	TUN-0305	0.1	8.0	
ACL-1172	TUN-0306	0.2	7.7	
ACL-1193	TUN-0332	0.4	7.7	
ACL-1194	TUN-0333	0.3	5.7	
ACL-1195	TUN-0334	0.1	4.7	

Table 3. (continued)

Laboratory Number	Field Sample Number	Percentage of N in sample by weight	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)	Sample Origin
ACL-1196	TUN-0335	0.1	3.9	
ACL-1197	TUN-0336	0.3	8.1	
ACL-1203	TUN-0342	0.4	8.2	
ACL-1204	TUN-0343	0.2	5.2	
ACL-1205	TUN-0344	0.2	7.3	
ACL-1206	TUN-0345	0.1	8.4	
ACL-1207	TUN-0346	0.0	4.8	
ACL-1213	TUN-0352	0.2	9.6	
ACL-1214	TUN-0353	0.3	6.4	
ACL-1215	TUN-0354	0.1	5.1	
ACL-1216	TUN-0355	0.1	4.9	
ACL-1217	TUN-0356	0.1	4.4	
ACL-1226	TUN-0367	0.3	14.9	
ACL-1227	TUN-0368	0.1	4.7	
ACL-1228	TUN-0369	0.2	4.7	
ACL-1229	TUN-0370	0.1	4.8	
ACL-1230	TUN-0371	0.1	7.0	
ACL-1239	TUN-0382	0.4	8.6	
ACL-1240	TUN-0383	0.4	6.7	
ACL-1241	TUN-0384	0.2	7.0	
ACL-1242	TUN-0385	0.1	6.0	
ACL-1243	TUN-0386	0.1	5.3	
ACL-1244	TUN-0387	0.4	8.3	
ACL-1245	TUN-0388	0.3	7.2	
ACL-1246	TUN-0389	0.2	6.2	
ACL-1247	TUN-0390	0.2	5.1	
ACL-1248	TUN-0391	0.3	4.5	
ACL-1257	TUN-0402	0.5	8.7	
ACL-1258	TUN-0403	0.3	6.7	
ACL-1259	TUN-0404	0.3	7.7	
ACL-1260	TUN-0405	0.2	6.8	
ACL-1273	TUN-0422	0.2	10.8	
ACL-1274	TUN-0423	0.4	6.0	
ACL-1275	TUN-0424	0.2	5.4	
ACL-1276	TUN-0425	0.2	6.8	
ACL-1277	TUN-0426	0.3	6.5	
ACL-1278	TUN-0427	0.4	8.7	
ACL-1279	TUN-0428	0.3	6.8	
ACL-1280	TUN-0429	0.4	4.8	
ACL-1281	TUN-0430	0.1	8.8	
ACL-1282	TUN-0431	0.2	9.7	
ACL-1290	TUN-0442	0.3	9.2	
ACL-1291	TUN-0443	0.5	6.6	
ACL-1292	TUN-0444	0.3	3.5	
ACL-1295	TUN-0445	0.1	4.4	
ACL-1301	TUN-0462	0.2	6.8	
ACL-1302	TUN-0463	0.2	5.1	
ACL-1303	TUN-0464	0.3	4.1	
ACL-1304	TUN-0465	4.6	4.4	
ACL-1305	TUN-0467	0.6	7.5	
ACL-1306	TUN-0468	0.3	6.3	
ACL-1307	TUN-0469	0.3	4.7	
ACL-1308	TUN-0470	0.2	5.6	
ACL-1321	TUN-0487	0.4	7.5	
ACL-1322	TUN-0488	0.3	8.4	

Table 3. (continued)

Laboratory Number	Field Sample Number	Percentage of N in sample by weight	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)	Sample Origin
ACL-1323	TUN-0489	0.4	6.0	
ACL-1324	TUN-0490	0.2	8.2	
ACL-1326	TUN-0492	0.2	8.4	
ACL-1327	TUN-0493	0.3	5.4	
ACL-1328	TUN-0494	0.2	5.1	
ACL-1329	TUN-0495	0.2	3.8	
ACL-1330	TUN-0497	0.3	7.4	
ACL-1331	TUN-0498	0.2	4.8	
ACL-1332	TUN-0499	0.2	6.0	
ACL-1333	TUN-0502	0.4	7.9	
ACL-1334	TUN-0507	0.1	8.8	
ACL-1335	TUN-0512	0.4	9.2	
ACL-1348	TUN-0537	0.1	9.1	
ACL-1349	TUN-0538	0.1	7.3	
ACL-1350	TUN-0539	0.1	9.3	
ACL-1351	TUN-0540	0.3	9.1	
ACL-1352	TUN-0542	0.3	7.5	
ACL-1353	TUN-0543	0.2	4.9	
ACL-1354	TUN-0544	0.2	4.2	
ACL-1355	TUN-0545	0.2	4.4	
ACL-1359	TUN-0552	0.3	7.7	
ACL-1360	TUN-0553	0.2	5.5	
ACL-1361	TUN-0554	0.4	4.3	
ACL-1362	TUN-0555	0.7	3.8	
ACL-1371	TUN-0572	0.4	9.7	
ACL-1372	TUN-0573	0.3	8.0	
ACL-1373	TUN-0574	0.2	6.5	
ACL-1374	TUN-0575	0.2	7.1	
ACL-1384	TUN-0592	0.1	6.8	
ACL-1385	TUN-0593	0.0	4.6	
ACL-1386	TUN-0594	0.1	5.1	
ACL-1387	TUN-0595	0.1	3.6	

mean $\delta^{15}\text{N}_{(\text{AIR})} = 2.2\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 35$). However, ethnoarchaeological soil samples collected from known fish processing areas exhibit mean $\delta^{15}\text{N}_{(\text{AIR})} = 13.4\text{‰} \pm 0.4\text{‰}$ (1σ , $n = 49$); we interpret the much higher nitrogen isotope values from the fish processing areas as evidence of marine-derived ^{15}N . Ethnoarchaeological soil samples from a historic semisubterranean structure in Tununak exhibited nitrogen isotope values that were intermediate between the offsite and fish processing areas, and samples from the sod house exhibited mean $\delta^{15}\text{N}_{(\text{AIR})} = 6.8\text{‰} \pm 0.2\text{‰}$ (1σ , $n = 105$).

There is a statistically significant difference in $\delta^{15}\text{N}$ values from the fish processing areas and the semisubterranean structures and the $\delta^{15}\text{N}$ values from offsite areas. We interpret this difference as the result of enrichment in ^{15}N as marine-derived nitrogen from fish and marine

mammals is incorporated into the soil during processing, storing, and discarding these products. Importantly, high $\delta^{15}\text{N}$ values are present in ethnoarchaeological soils in areas currently used for fish processing as well as in soils collected from a historic semisubterranean house that has been abandoned for more than fifty years. The use of nitrogen isotope analysis of archaeological soils to identify marine resource use is a novel application of a well-established technique in archaeology. We argue that this new method could be particularly useful for a minimally invasive examination of archaeological sites and activity areas, including processing and storing marine and anadromous fish resources as well as animals that consume these products. Finally, nitrogen isotope analysis of anthropogenically modified soils could also be used to examine long-term human impacts on arctic ecosystems.

Table 4. Descriptive statistics from nitrogen isotope data from all ethnoarchaeological samples collected from Nelson Island.

	$\delta^{15}\text{N}_{(\text{AIR})}$ (‰)
Offsite Area	
Mean	2.2
Standard Error	0.4
Median	1.9
Standard Deviation	2.4
Sample Variance	5.7
Range	14.2
Minimum	-0.6
Maximum	13.7
Count	35
Fish Processing Area	
Mean	13.4
Standard Error	0.4
Median	14.0
Standard Deviation	2.7
Sample Variance	7.5
Range	16.6
Minimum	2.9
Maximum	19.5
Count	49
Sod House	
Mean	6.8
Standard Error	0.2
Median	6.8
Standard Deviation	2.0
Sample Variance	3.9
Range	11.4
Minimum	3.5
Maximum	14.9
Count	105

ACKNOWLEDGEMENTS

The authors gratefully acknowledge generous funding from the National Science Foundation Office of Polar Programs (ARC-0710687) and logistical support from the Tununak Traditional Elder Council, the U.S. Fish and Wildlife Service (Anchorage and Bethel offices), the Archaeological Chemistry Laboratory at Arizona State University, and the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University. We are also very grateful for the field contributions of our field assistant and interpreter, Pauline N. Haas, and our field technicians, Ashley Evans and Glendee Ane Osborne, as well as the invaluable laboratory assistance of Research Associates Kristin Nado and Eleni Anna Prevedorou and Assistant Research Scientist Natalya Zolotova. Finally, the manuscript was improved thanks to three anonymous reviewers, Owen Mason of the *Alaska Journal of Anthropology*, Anna Kerttula and Adrian Dahood of the National Science Foundation; we thank them for their time and expertise.

NOTES

1. In fish processing area 1, the sand, silty sand, clayey sand and loam soils were characterized as 10YR 2/2 (Munsell color chart “very dark brown”), 10YR 3/1 (“very dark gray”), 10YR 3/2 (“very dark grayish brown”), and 10YR 2/1 (“black”). In fish processing area 2, the silty sand and loamy sand soils were characterized as 10YR 2/1 (“black”), 10YR 2/2 (“very dark brown”), 10YR 3/1 (“very dark gray”), and 10YR 3/2 (“very dark grayish brown”). Finally, in fish processing area 3, the silty loam and silty clay loam soils were characterized as 10YR 3/1 (“very dark gray”), and 10YR 4/2 (“dark grayish brown”).
2. The sandy clay, silty loam, and sandy loam soils from the semisubterranean structure were characterized as 10YR 2/2 and 4/3 (Munsell color chart “very dark brown” and “brown”) and 10YR 3/2 (“very dark grayish brown”).
3. In offsite area 1, clay loam soils were characterized as 7.5YR 3/2 and 4/2 (Munsell color chart “dark brown” and “brown”) and 5Y 3/2 (“dark olive gray”). In offsite area 2, loamy clay and clay soils ranged between 10YR 2/1 (“black”) and 10YR 4/3 (“brown”). Finally, offsite area 3 soils ranged between 10YR 2/1 (“black”)

and 10YR 3/1 ("very dark gray") and were sandy silty loam soils with a loose and friable texture.

REFERENCES

- Ager, Thomas A., and Lynn Price Ager
1980 Ethnobotany of the Eskimos of Nelson Island, Alaska. *Arctic Anthropology* 17:26–48.
- Ambrose, Stanley H.
1990 Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. *Journal of Archaeological Science* 17:430–451.
1991 Effects of Diet, Climate and Physiology on Nitrogen Isotope Abundances in Terrestrial Foodwebs. *Journal of Archaeological Science* 18:293–317.
- Ambrose, Stanley H., and Michael J. DeNiro
1987 Bone Nitrogen Isotope Composition and Climate. *Nature* 325:201.
- Andronikov, Sergei V., Donald A. Davidson, and Ronald B. Spiers
2000 Variability in Contamination by Heavy Metals: Sampling Implications. *Water, Air, & Soil Pollution* 120:29–45.
- Atwell, Lisa, Keith A. Hobson, and Harold E. Welch
1998 Biomagnification and Bioaccumulation of Mercury in an Arctic Marine Food Web: Insights from Stable Nitrogen Isotope Analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1114–1121.
- Balasse, Marie, Herve Bocherens, Andre Mariotti, and Stanley H. Ambrose
2001 Detection of Dietary Changes by Intra-Tooth Carbon and Nitrogen Isotopic Analysis: An Experimental Study of Dentine Collagen of Cattle (*Bos taurus*). *Journal of Archaeological Science* 28:235–245.
- Barker, James H.
1993 *Always Getting Ready / Upterrlainarluta: Yup'ik Eskimo Subsistence in Southwest Alaska*. University of Washington Press, Seattle.
- Barto, David L.
2004 Assessing the Production of Sockeye Salmon (*Oncorhynchus nerka*) at Chilkat Lake, Southeast Alaska, Using Current Trophic Conditions and the Paleolimnologic Sediment Record, M.Sc. thesis, University of Alaska Fairbanks, Alaska.
- Ben-David, M., R. T. Bowyer, L. K. Duffy, D. D. Roby, and D. M. Schell
1998a Social Behavior and Ecosystem Processes: River Otter Latrines and Nutrient Dynamics of Terrestrial Vegetation. *Ecology* 79:2567–2571.
- Ben-David, M., T. A. Hanley, and D. M. Schell
1998b Fertilization of Terrestrial Vegetation by Spawning Pacific Salmon: The Role of Flooding and Predator Activity. *Oikos* 83:47–55.
- Bergstrom, Dana M., George R. Stewart, Patricia M. Selkirk, and Susanne Schmidt
2002 ¹⁵N Natural Abundance of Fossil Peat Reflects the Influence of Animal-Derived Nitrogen on Vegetation. *Oecologia* 130:309–314.
- Bilby, R. E., B. R. Fransen, and P. A. Bisson
1996 Incorporation of Nitrogen and Carbon from Spawning Coho Salmon into the Trophic System of Small Streams: Evidence from Stable Isotopes. *Canadian Journal of Fisheries and Aquatic Sciences* 53:164–173.
- Binkley, D., P. Sollins, and W. B. McGill
1985 Natural Abundance of Nitrogen-15 as a Tool for Tracing Alder-Fixed Nitrogen. *Soil Science Society of America Journal* 49:444–447.
- Blackmer, A. M., and J. M. Bremner
1977 Nitrogen Isotope Discrimination in Denitrification of Nitrate in Soils. *Soil Biology and Biochemistry* 9:73–77.
- Bogaard, A., Tim H. E. Heaton, P. Poulton, and I. Merbach
2007 The Impact of Manuring on Nitrogen Isotope Ratios in Cereals: Archaeological Implications for Reconstruction of Diet and Crop Management Practices. *Journal of Archaeological Science* 34:335–343.
- Born, Erik W., P. Outridge, F. F. Riget, K. A. Hobson, and R. Dietz
2003 Population Substructure of North Atlantic Minke Whales (*Balaenoptera acutorostrata*) Inferred from Regional Variation of Elemental and Stable Isotopic Signatures in Tissues. *Journal of Marine Systems* 43(1–2):1–17.
- Burton, Robert K., and Paul L. Koch
1999 Isotopic Tracking of Foraging and Long-Distance Migration in Northeastern Pacific Pinnipeds. *Oecologia* 119:578–585.
- Caldwell, P. V., A. A. Adams, C. P. Niewoehner, M. J. Vepraskas, and J. D. Gregory
2005 Sampling Device to Extract Intact Cores in Saturated Organic Soils. *Soil Science Society of America Journal* 69:2071–2075.

- Caraveo-Patiño, Javier, Keith Hobson, and Luis Soto
2007 Feeding Ecology of Gray Whales Inferred from Stable-Carbon and Nitrogen Isotopic Analysis of Baleen Plates. *Hydrobiologia* 586(1):17–25.
- Chapin, F.S., N. Fetcher, K. Kielland, K.R. Everett, and A.E. Linkins
1988 Productivity and Nutrient Cycling of Alaskan Tundra: Enhancement by Flowing Soil Water. *Ecology* 69:693–702.
- Chapin, F.S., L. Moilanen, and K. Kielland
1993 Preferential Use of Organic Nitrogen for Growth by a Non-Mycorrhizal Arctic Sedge. *Nature* 361:150–153.
- Chapin, F.S., and G.R. Shaver
1981 Changes in Soil Properties and Vegetation Following Disturbance of Alaskan Arctic Tundra. *Journal of Applied Ecology* 18:605–617.
- Cheng, H.H., J.M. Bremner, and A.P. Edwards
1964 Variations of Nitrogen-15 Abundance in Soils. *Science* 146:1574–1575.
- Choi, W.J., S.M. Lee, H.M. Ro, K.C. Kim, and S.H. Yoo
2002 Natural ^{15}N Abundances of Maize and Soil Amended with Urea and Composted Pig Manure. *Plant and Soil* 245:223–232.
- Choi, W.J., H.M. Ro, and E.A. Hobbie
2003 Patterns of Natural ^{15}N in Soils and Plants from Chemically and Organically Fertilized Uplands. *Soil Biology and Biochemistry* 35:1493–1500.
- Commisso, R.G., and D.E. Nelson
2006 Modern Plant $\delta^{15}\text{N}$ Values Reflect Ancient Human Activity. *Journal of Archaeological Science* 33:1167–1176.
- 2007 Patterns of Plant $\delta^{15}\text{N}$ Values on a Greenland Norse Farm. *Journal of Archaeological Science* 34(3):440–450.
- 2008 Correlation between Modern Plant $\delta^{15}\text{N}$ Values and Activity Areas of Medieval Norse Farms. *Journal of Archaeological Science* 35:492–504.
- 2010 Stable Nitrogen Isotopic Examination of Norse Sites in the Western Settlement of Greenland. *Journal of Archaeological Science* 37:1233–1240.
- Croll, D.A., J.L. Maron, J.A. Estes, E.M. Danner, and G.V. Byrd
2005 Introduced Predators Transform Subarctic Islands from Grassland to Tundra. *Science* 307:1959–1961.
- Dehn, L.A., E.H. Follmann, D.L. Thomas, G.G. Sheffield, C. Rosa, L.K. Duffy and T.M. O'Hara
2006 Trophic Relationships in an Arctic Food Web and Implications for Trace Metal Transfer. *Science of the Total Environment* 362:103–123.
- DeNiro, Michael J., and Samuel Epstein
1981 Influence of Diet on the Distribution of Nitrogen Isotopes in Animals. *Geochimica et Cosmochimica Acta* 45:341–351.
- Drucker, D., and H. Bocherens
2004 Carbon and Nitrogen Stable Isotopes as Tracers of Change in Diet Breadth during Middle and Upper Palaeolithic in Europe. *International Journal of Osteoarchaeology* 14:162–177.
- Dunton, Kenneth H., Susan M. Saupe, Alexander N. Golikov, Donald M. Schell, and Susan V. Schonberg
1989 Trophic Relationships and Isotopic Gradients among Arctic and Subarctic Marine Fauna. *Marine Ecology Progress Series* 56:89–97.
- Entwistle, Jane A., Peter W. Abrahams, and R.A. Dodgshon
2000 The Geoarchaeological Significance and Spatial Variability of a Range of Physical and Chemical Soil Properties from a Former Habitation Site, Isle of Skye. *Journal of Archaeological Science* 27:287–303.
- Entwistle, Jane A., K.J.W. McCaffrey, and R.A. Dodgshon
2007 Geostatistical and Multi-Elemental Analysis of Soils to Interpret Land-Use History in the Hebrides, Scotland. *Geoarchaeology* 22:391–415.
- Erskine, Peter D., Dana M. Bergstrom, Susanne Schmidt, George R. Stewart, Craig E. Tweedie, and Justine D. Shaw
1998 Subantarctic Macquarie Island—A Model Ecosystem for Studying Animal-Derived Nitrogen Sources Using ^{15}N Natural Abundance. *Oecologia* 117:187–193.
- Evans, R.D.
2007 Soil Nitrogen Isotope Composition. In *Stable Isotopes in Ecology and Environmental Science*, edited by R. Michener and K. Lajtha, pp. 83–98. Blackwell, Malden, MA.
- Feek, D.T., J.R. Flenley, P.I. Chester, N. Welikala, E.A. Matisoo-Smith, and G.W. Tannock
2006 A Modified Sampler for Uncontaminated DNA Cores from Soft Sediments. *Journal of Archaeological Science* 33:573–574.

- Fernández, Jorge, Héctor O. Panarello, and Juan Schobinger
1999 The Inka Mummy from Mount Aconcagua: Decoding the Geographic Origin of the "Messenger to the Deities" by Means of Stable Carbon, Nitrogen, and Sulfur Isotope Analysis. *Geoarchaeology: An International Journal* 14:27–46.
- Fienup-Riordan, Ann
1983 *The Nelson Island Eskimo: Social Structure and Ritual Distribution*. Alaska Pacific University Press, Anchorage.
1986 *When Our Bad Season Comes: A Cultural Account of Subsistence Harvesting and Harvest Disruption on the Yukon Delta*. Aurora Monograph Series, no. 1. Alaska Anthropological Association, Anchorage.
- Finney, Bruce P., Irene Gregory-Eaves, Jon Sweetman, Marianne S. V. Douglas, and John P. Smol
2000 Impacts of Climatic Change and Fishing on Pacific Salmon Abundance over the Past 300 Years. *Science* 290:795–799.
- Finucane, B.
2007 Mummies, Maize, and Manure: Multi-Tissue Stable Isotope Analysis of Late Prehistoric Human Remains from the Ayacucho Valley, Peru. *Journal of Archaeological Science* 34:2115–2124.
- Frink, Liam, and Kelly J. Knudson
2010 Using Ethnoarchaeology and Soils Chemistry to Examine Herring and Salmon Fisheries on the Arctic Alaskan Coast. *North American Archaeologist* 31:221–247.
- Frink, Lisa
2002 Fish Tales: Women and Decision-Making in Western Alaska. In *Many Faces of Gender: Roles and Relationships through Time in Indigenous Northern Communities*, edited by Lisa Frink, Rita S. Shepard, and Gregory A. Reinhardt, pp. 93–110. University Press of Colorado, Boulder.
2007 Storage and Status in Precolonial and Colonial Coastal Western Alaska. *Current Anthropology* 48:349–374.
2009 The Identity Division of Labor in Native Alaska. *American Anthropologist* 111:21–29.
- Frink, Lisa, Brian W. Hoffman and Robert D. Shaw
2003 Ulu Knife Use in Western Alaska: A Comparative Ethnoarchaeological Study. *Current Anthropology* 44:116–121.
- Fry, Brian
1991 Stable Isotope Diagrams of Freshwater Food Webs. *Ecology* 72:2293–2297.
- Fuller, Benjamin T., James L. Fuller, Nancy E. Sage, David A. Harris, Tamsin C. O'Connell, and Robert E. M. Hedges
2004 Nitrogen Balance and $\delta^{15}\text{N}$: Why You're Not What You Eat during Pregnancy. *Rapid Communications in Mass Spectrometry* 18:2889–2896.
2005 Nitrogen Balance and $\delta^{15}\text{N}$: Why You're Not What You Eat during Nutritional Stress. *Rapid Communications in Mass Spectrometry* 19:2497–2506.
- Fuller, Benjamin T., Michael P. Richards, and Simon Mays
2003 Stable Carbon and Nitrogen Isotope Variations in Tooth Dentine Serial Sections from Wharram Percy. *Journal of Archaeological Science* 30:1673–1684.
- Gebauer, G., and E. D. Schulze
1991 Carbon and Nitrogen Isotope Ratios in Different Compartments of a Healthy and a Declining *Picea abies* Forest in the Fichtelgebirge, NE Bavaria. *Oecologia* 87:198–207.
- Gendron, Diane, Sergio Aguñiga, and José D. Carriquiry
2001 $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ in Skin Biopsy Samples: A Note on Their Applicability for Examining the Relative Trophic Level in Three Rorqual Species. *Journal of Cetacean Research and Management* 3(1):41–44.
- Gough, L. P., R. C. Severson, and H. T. Shacklette
1988 Element Concentrations in Soils and Other Surface Materials of Alaska: An Account of the Concentrations of 43 Chemical Elements, Ash, and pH in Soil and Other Unconsolidated Regolith Samples. U.S. Geological Survey Professional Paper no. 1458.
- Griffiths, Katherine, Neal Michelutti, Jules Blais, Lynda Kimpe, and John Smol
2010 Comparing Nitrogen Isotopic Signals between Bulk Sediments and Invertebrate Remains in High Arctic Seabird-Influenced Ponds. *Journal of Paleolimnology* 44:405–412.
- Hart, S. C., and D. D. Myrold
1996 ^{15}N Tracer Studies of Soil Nitrogen Transformations. In *Mass Spectrometry of Soils*, edited by T. W. Boutton and S. Yamasaki, pp. 225–246. Marcel Dekker, Inc., New York.
- Haslam, Rob, and Mark Tibbett
2004 Sampling and Analyzing Metals in Soils for Archaeological Prospection: A Critique. *Geoarchaeology* 19:731–751.
- Hatch, K. A., M. A. Crawford, A. W. Kunz, S. R. Thomsen, D. L. Eggett, S. T. Nelson, and B. L. Roeder
2006 An Objective Means of Diagnosing Anorexia Nervosa and Bulimia Nervosa using $^{15}\text{N}/^{14}\text{N}$ and

- $^{13}\text{C}/^{12}\text{C}$ Ratios in Hair. *Rapid Communications in Mass Spectrometry* 20:3367–3373.
- Hedges, R. E. M., and L. M. Reynard
2007 Nitrogen Isotopes and the Trophic Level of Humans in Archaeology. *Journal of Archaeological Science* 34:1240–1251.
- Hedin, L. O., J. C. von Fischer, N. E. Ostrom, B. P. Kennedy, M. G. Brown, and G. P. Robertson
1998 Thermodynamic Constraints on Nitrogen Transformations and Other Biogeochemical Processes at Soil-Stream Interfaces. *Ecology* 79:684–703.
- Herman, D. P., D. G. Burrows, P. R. Wade, J. W. Durban, C. O. Matkin, R. G. LeDuc, L. G. Barrett-Lennard, and M. M. Krahn
2005 Feeding Ecology of Eastern North Pacific Killer Whales *Orcinus orca* from Fatty Acid, Stable Isotope, and Organochlorine Analyses of Blubber Biopsies. *Marine Ecology Progress Series* 302:275–291.
- Hilderbrand, G. V., T. A. Hanley, C. T. Robbins, and C. C. Schwartz
1999 Role of Brown Bears (*Ursus arctos*) in the Flow of Marine Nitrogen into a Terrestrial Ecosystem. *Oecologia* 121:546–550.
- Hirons, Amy
2001 Trophic Dynamics of Pinniped Populations in Alaska Using Stable Carbon and Nitrogen Isotope Ratios. Unpublished Ph.D. dissertation, School of Fisheries and Ocean Science, University of Alaska Fairbanks.
- Hobbie, E. A., S. A. Macko, and H. H. Shugart
1998 Patterns in N Dynamics and N Isotopes during Primary Succession in Glacier Bay, Alaska. *Chemical Geology* 152:3–11.
- Hobbie, E. A., S. A. Macko, and M. Williams
2000 Correlations between Foliar $\delta^{15}\text{N}$ and Nitrogen Concentrations May Indicate Plant-Mycorrhizal Interactions. *Oecologia* 122:273–283.
- Hobson, Keith A., Gabriel J. Bowen, Leonard I. Wassenaar, Yves Ferrand, and Herve Lormee
2004 Using Stable Hydrogen and Oxygen Isotope Measurements of Feathers to Infer Geographical Origins of Migrating European Birds. *Oecologia* 141:477–488.
- Hobson, Keith A., and Don M. Schell
1998 Stable Carbon and Nitrogen Isotope Patterns in Baleen from Eastern Arctic Bowhead Whales (*Balaena mysticetus*). *Canadian Journal of Fisheries and Aquatic Sciences* 55(12):2601–2607.
- Hobson, Keith A., and W. A. Montevecchi
1991 Stable Isotopic Determinations of Trophic Relationships of Great Auks. *Oecologia* 87:528–531.
- Hobson, Keith A., J. F. Piatt, and J. Pittocchelli
1994 Using Stable Isotopes to Determine Seabird Trophic Relationships. *Journal of Animal Ecology* 63:786–798.
- Hobson, Keith A., J. L. Sease, and J. F. Piatt
1997 Investigating Trophic Relationships of Pinnipeds in Alaska and Washington Using Stable Isotope Ratios of Nitrogen and Carbon. *Marine Mammal Science* 13:114–132.
- Hobson, Keith A., Elizabeth H. Sinclair, Anne E. York, James R. Thomason, and Richard E. Merrick
2004 Retrospective Isotopic Analyses of Steller Sea Lion Tooth Annuli and Sea-Bird Feathers: A Cross-Taxa Approach to Investigating Regime and Dietary Shifts in the Gulf of Alaska. *Marine Mammal Science* 20:621–638.
- Hobson, Keith A., and H. E. Welch
1992 Determination of Trophic Relationships within a High Arctic Marine Food Web Using $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Analysis. *Marine Ecology Progress Series* 84:9–18.
- Hoekstra, P. F., L. A. Dehn, J. C. George, K. R. Solomon, D. C. G. Muir, and T. M. O'Hara
2002 Trophic Ecology of Bowhead Whales (*Balaena mysticetus*) Compared with That of Other Arctic Marine Biota as Interpreted from Carbon-, Nitrogen-, and Sulfur-Isotope Signatures. *Canadian Journal of Zoology* 80:223–231.
- Högberg, Peter
1997 ^{15}N Natural Abundance in Soil-Plant Systems. *New Phytologist* 137:179–203.
- Holliday, Vance T., Denise Lawrence-Zuniga, and Victor Buchli
2010 Prologue to Uses of Chemical Residues to Make Statements about Human Activities. *Journal of Archaeological Method and Theory* 17:175–182.
- Holtham, Anita J., Irene Gregory-Eaves, Marlow G. Pellatt, Daniel T. Selbie, Laura Stewart, Bruce P. Finney, and John P. Smol
2004 The Influence of Flushing Rates, Terrestrial Input and Low Salmon Escapement Densities on Paleolimnological Reconstructions of Sockeye Salmon (*Oncorhynchus nerka*) Nutrient Dynam-

- ics in Alaska and British Columbia. *Journal of Paleolimnology* 32:255–271.
- Hu, F. S., B. P. Finney, and L. B. Brubaker
2001 Effects of Holocene Alnus Expansion on Aquatic Productivity, Nitrogen Cycling, and Soil Development in Southwestern Alaska. *Ecosystems* 4:358–368.
- Hübner, H.
1986 Isotope Effects of Nitrogen in the Soil and Biosphere. In *Handbook of Environmental Isotope Geochemistry*. Vol. 2: *The Terrestrial Environment*, edited by P. Fritz and J. Ch. Fontes, pp. 361–425. Elsevier, Amsterdam.
- Jay, Mandy, and Michael P. Richards
2006 Diet in the Iron Age Cemetery Population at Wetwang Slack, East Yorkshire, UK: Carbon and Nitrogen Stable Isotope Evidence. *Journal of Archaeological Science* 33:653–662.
- Jørkov, Marie Louise S., Jan Heinemeier, and Niels Lynnerup
2007 Evaluating Bone Collagen Extraction Methods for Stable Isotope Analysis in Dietary Studies. *Journal of Archaeological Science* 34:1824–1829.
- Kaeriyama, M., M. Nakamura, R. Edpalina, J. R. Bower, H. Yamaguchi, R. V. Walker, and K. W. Myers
2004 Change in Feeding Ecology and Trophic Dynamics of Pacific Salmon (*Oncorhynchus* spp.) in the Central Gulf of Alaska in Relation to Climate Events. *Fisheries Oceanography* 13:197–207.
- Katzenberg, M. Anne
2000 Stable Isotope Analysis: A Tool for Studying Past Diet, Demography and Life History. In *Biological Anthropology of the Human Skeleton*, edited by M. Anne Katzenberg and Shelley R. Saunders, pp. 305–328. Wiley-Liss, New York.
- Katzenberg, M. Anne, and Roman G. Harrison
1997 What's in a Bone? Recent Advances in Archaeological Bone Chemistry. *Journal of Archaeological Research* 5:265–293.
- Kaye, J. P., D. Binkley, and C. Rhoades
2003 Stable Soil Nitrogen Accumulation and Flexible Organic Matter Stoichiometry during Primary Floodplain Succession. *Biogeochemistry* 63:1–22.
- Keatley, Bronwyn E., Jules M. Blais, Marianne S. V. Douglas, Irene Gregory-Eaves, Mark L. Mallory, Neal Michelutti, and John P. Smol
2011 Historical Seabird Population Dynamics and Their Effects on Arctic Pond Ecosystems: A Multi-Proxy Paleolimnological Study from Cape Vera, Devon Island, Arctic Canada. *Fundamental and Applied Limnology* 179:51–66.
- Kelly, Jeffrey F.
2000 Stable Isotopes of Carbon and Nitrogen in the Study of Avian and Mammalian Trophic Ecology. *Canadian Journal of Zoology* 78:1–27.
- Kline, Thomas C., Jr.
1997 Confirming Forage Fish Food Web Dependencies in Prince William Sound Using Natural Stable Isotope Tracers. In *Forage Fishes in Marine Ecosystems*. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems, Anchorage, Alaska, pp. 257–269. Alaska Sea Grant College Program Report no. 97-01, University of Alaska Fairbanks.
- 1999 Temporal and Spatial Variability of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ in Pelagic Biota of Prince William Sound, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 56:94–117.
- Kline, T. C., Jr., J. J. Coering, O. A. Mathisen, P. H. Poe, and P. L. Parker
1990 Recycling of Elements Transported Upstream by Runs of Pacific Salmon: I. $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ Evidence in Sashin Creek, Southeastern Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 47:136–144.
- Kline, T. C., Jr., J. J. Coering, O. A. Mathisen, P. H. Poe, P. L. Parker, and R. S. Schalan
1993 Recycling of Elements Transported Upstream by Runs of Pacific Salmon: II. $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ Evidence in the Kvichak River Watershed, Bristol Bay, Southwestern Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* 50:2350–2365.
- Knudson, Kelly J., Arthur E. Aufderheide, and Jane E. Buikstra
2007 Seasonality and Paleodiet in the Chiribaya Polity of Southern Peru. *Journal of Archaeological Science* 34:451–462.
- Knudson, Kelly J., and Liam Frink
2010a Ethnoarchaeological Analysis of Arctic Fish Processing: Chemical Characterization of Soils on Nelson Island, Alaska. *Journal of Archaeological Science* 37:769–783.
- 2010b Soil Chemical Signatures of a Historic Sod House: Activity Area Analysis of an Arctic Semi-Subterranean Structure on Nelson Island, Alaska. *Archaeological and Anthropological Sciences* 2:265–282.

- Knudson, Kelly J., Lisa Frink, Brian W. Hoffman, and T. Douglas Price
2004 Chemical Characterization of Arctic Soils: Activity Area Analysis in Contemporary Yup'ik Fish Camps Using ICP-AES. *Journal of Archaeological Science* 31:443–356.
- Koch, Paul L.
1998 Isotopic Reconstruction of Past Continental Environments. *Annual Review of Earth and Planetary Sciences* 26:573–613.
2007 Isotopic Study of the Biology of Modern and Fossil Vertebrates. In *Stable Isotopes in Ecology and Environmental Science*, edited by R. Michener and K. Lajtha, pp. 99–154. Blackwell, Malden, MA.
- Koerner, W., E. Dambrine, J. L. Dupouey, and M. Benoit
1999 $\delta^{15}\text{N}$ of Forest Soil and Understorey Vegetation Reflect the Former Agricultural Land Use. *Oecologia* 121:421–425.
- Krummel, Eva M., Michael Scheer, Irene Gregory-Eaves, Robie W. Macdonald, Lynda E. Kimpe, John P. Smol, Bruce Finney, and Jules M. Blais
2009 Historical Analysis of Salmon-Derived Polychlorinated Biphenyls (PCBs) in Lake Sediments. *Science of the Total Environment* 407:1977–1989.
- Kurle, Carolyn M., and Carolyn J. Gudmundson
2007 Regional Differences in Foraging of Young-of-the-Year Steller Sea Lions *Eumetopias jubatus* in Alaska: Stable Carbon and Nitrogen Isotope Ratios in Blood. *Marine Ecology Progress Series* 342:303–310.
- Kurle, Carolyn M., and Graham A. J. Worthy
2001 Stable Isotope Assessment of Temporal and Geographic Differences in Feeding Ecology of Northern Fur Seals (*Callorhinus ursinus*) and Their Prey. *Oecologia* 126:254–265.
2002 Stable Nitrogen and Carbon Isotope Ratios in Multiple Tissues of the Northern Fur Seal (*Callorhinus ursinus*): Implications for Dietary and Migratory Reconstructions. *Marine Ecology Progress Series* 236:289–300.
- Lark, R. Murray
2005 Exploring Scale Dependent Correlation of Soil Properties by Nested Sampling. *European Journal of Soil Science* 56:307–317.
- Lee, Sang Heon, Donald M. Schell, Trent L. McDonald, and W. John Richardson
2005 Regional and Seasonal Feeding by Bowhead Whales *Balaena mysticetus* as Indicated by Stable Isotope Ratios. *Marine Ecology Progress Series* 285:271–285.
- Lesage, Veronique, Mike O. Hammill, and Kit M. Kovacs
2002 Diet-Tissue Fractionation of Stable Carbon and Nitrogen Isotopes in Phocid Seals. *Marine Mammal Science* 18(1):182–193.
- López Varela, Sandra L., and Christopher D. Dore
2010 Social Spaces of Daily Life: A Reflexive Approach to the Analysis of Chemical Residues by Multivariate Spatial Analysis. *Journal of Archaeological Method and Theory* 17:249–278.
- Lyle, W. M., I. F. Palmer, Jr., J. G. Bolm, and T. O. Flett
1982 Hydrocarbon Reservoir and Source-Rock Characteristics from Selected Areas of Southwestern Alaska. Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, Juneau.
- Macko, S. A., G. Lubec, M. Teschler-Nicola, V. Andrushevich, and M. H. Engel
1999 The Ice Man's Diet as Reflected by the Stable Nitrogen and Carbon Isotopic Composition of His Hair. *FASEB Journal* 13:559–562.
- MacManus, Dean A., Kolla Venkatarathnam, David M. Hopkins, and C. Hans Nelson
1974 Yukon River Sediment on the Northernmost Bering Sea Shelf. *Journal of Sedimentary Research* 44:1052–1060.
- Mariotti, Andre
1983 Atmospheric Nitrogen Is a Reliable Standard for Natural ^{15}N Abundance Measurements. *Nature* 303:685–687.
- Maron, John L., James A. Estes, Donald A. Croll, Eric M. Danner, Sarah C. Elmendorf, and Stacey L. Buckelew
2006 An Introduced Predator Alters Aleutian Island Plant Communities by Thwarting Nutrient Subsidies. *Ecological Monographs* 76:3–24.
- Meharg, Andrew A., Clare Deacon, Kevin J. Edwards, Margaret Donaldson, Donald A. Davidson, Christian Spring, Charles M. Scrimgeour, Jörg Feldmann, and A. Rabb
2006 Ancient Manuring Practices Pollute Arable Soils at the St Kilda World Heritage Site, Scottish North Atlantic. *Chemosphere* 64:1818–1828.
- Mekota, Anna-Maria, Gisela Grupe, Sandra Ufer, and Ullrich Cuntz
2006 Serial Analysis of Stable Nitrogen and Carbon Isotopes in Hair: Monitoring Starvation and

Recovery Phases of Patients Suffering from Anorexia Nervosa. *Rapid Communications in Mass Spectrometry* 20:1604–1610.

Michener, Robert H., and Les Kaufman

2007 Stable Isotope Ratios as Tracers in Marine Food Webs: An Update. In *Stable Isotopes in Ecology and Environmental Science*, edited by Robert H. Michener and Kate Lajtha, pp. 238–282. Blackwell, Malden, MA.

Middleton, William D., and T. Douglas Price

1996 Identification of Activity Areas by Multi-Element Characterization of Sediments from Modern and Archaeological House Floors Using Inductively Coupled Plasma-Atomic Emission Spectroscopy. *Journal of Archaeological Science* 23:673–687.

Minagawa, Masao, and Eitaro Wada

1984 Stepwise Enrichment of ^{15}N along Food Chains: Further Evidence and the Relation between $\delta^{15}\text{N}$ and Animal Age. *Geochimica et Cosmochimica Acta* 48:1135–1140.

Misarti, Nicole

2007 Six Thousand Years of Climate Change in the Northeast Pacific: An Interdisciplinary View of Maritime Ecosystems. Unpublished Ph.D. dissertation, School of Fisheries and Ocean Science, University of Alaska at Fairbanks.

Misarti, Nicole, Bruce P. Finney, Herbert Maschner, and Matthew J. Wooller

2009 Changes in Northeast Pacific Marine Ecosystems over the Last 4500 Years: Evidence from Stable Isotope Analysis of Bone Collagen from Archaeological Middens. *The Holocene* 19:1139–1151.

Misarti, Nicole, Bruce P. Finney, and Herbert Maschner

2011 Reconstructing Site Organization in the Eastern Aleutian Islands, Alaska using Multi-Element Chemical Analysis of Soils. *Journal of Archaeological Science* 38:1441–1455.

Nash, Sarah H., Andrea Bersamin, Alan R. Kristal, Scarlett E. Hopkins, Rebecca S. Church, Renee L. Pasker, Bret R. Luick, Gerald V. Mohatt, Bert B. Boyer, and Diane M. O'Brien

2012 Stable Nitrogen and Carbon Isotope Ratios Indicate Traditional and Market Food Intake in an Indigenous Circumpolar Population. *Journal of Nutrition* 142:84–90.

Nash, Sarah H., Alan R. Kristal, Bert B. Boyer, Irena B. King, Jordan S. Metzgar, and Diane M. O'Brien

2009 Relation between Stable Isotope Ratios in Human Red Blood Cells and Hair: Implications for

Using the Nitrogen Isotope Ratio of Hair as a Biomarker of Eicosapentaenoic Acid and Docosahexaenoic Acid. *American Journal of Clinical Nutrition* 90:1642–1647.

Natelhoffer, K. J., and B. Fry

1988 Controls on Natural Nitrogen-15 and Carbon-13 Abundances in Forest Soil Organic Matter. *Soil Science Society of America Journal* 52:1633–1640.

Newsome, S. D., M. A. Etnier, C. M. Kurle, J. R. Waldbauer, C. P. Chamberlain, and P. L. Koch

2007 Historic Decline in Primary Productivity in Western Gulf of Alaska and Eastern Bering Sea: Isotopic Analysis of Northern Fur Seal Teeth. *Marine Ecology Progress Series* 332:211–224.

O'Brien, Diane M., Alan R. Kristal, M. Alyssa Jeannet, Michael J. Wilkinson, Andrea Bersamin, and Bret Luick

2009 Red Blood Cell $\delta^{15}\text{N}$: A Novel Biomarker of Dietary Eicosapentaenoic Acid and Docosahexaenoic Acid Intake. *American Journal of Clinical Nutrition* 89:913–919.

Ohizumi, Hiroshi, and Nobuyuki Miyazaki

2001 Nitrogen and Carbon Stable Isotope Ratios in the Muscle of Dall's Porpoises, *Phocoenoides dalli*. In *Proceeding Abstracts of the 14th Biennial Conference on the Biology of Marine Mammals*, p. 160. Society of Marine Mammalogy, Vancouver, BC.

Pete, Mary C., Daniel E. Albrecht, and Ronald E. Kreher

1987 Subsistence Herring Fishing in the Nelson Island District and Northern Kuskokwim Bay. Alaska Department of Fish and Game, Division of Subsistence Technical Paper no. 160. Juneau.

Post, David M.

2002 Using Stable Isotopes to Estimate Trophic Position: Models, Methods, and Assumptions. *Ecology* 83:703–718.

Pye, Kenneth, Simon J. Blott, and David S. Wray

2006 Elemental Analysis of Soil Samples for Forensic Purposes by Inductively Coupled Plasma Mass Spectrometry—Precision Considerations. *Forensic Science International* 160:178–192.

Reimchen, T. E., D. Mathewson, M. D. Hocking, and J. Moran

2002 Isotopic Evidence for Enrichment of Salmon-Derived Nutrients in Vegetation, Soil, and Insects in Riparian Zones in Coastal British Columbia. *American Fisheries Society Symposium* 20:1–12.

- Rhoades, C., H. Oskarsson, D. Binkley, and R. Stottlemeyer
2001 Alder (*Alnus crispa*) Effects on Soils in Ecosystems of the Agashashok River Valley, Northwest Alaska. *Ecoscience* 8:89–95.
- Satterfield, F. R., and B. P. Finney
2002 Stable Isotope Analysis of Pacific Salmon: Insight into Trophic Status and Oceanographic Conditions over the Last Thirty Years. *Oceanography* 53:231–246.
- Schell, Donald M.
1992 Stable Isotope Analysis of 1987–1991 Zooplankton Samples and Bowhead Whale Tissues. OCS Study MMS 92-0020. Report to U.S. Minerals Management Service, Anchorage, AK, NTIS PB93-135879, National Technical Information Service, Springfield, VA.
2001 Carbon Isotope Ratio Variations in Bering Sea Biota: The Role of Anthropogenic Carbon Dioxide. *Limnology and Oceanography* 46:999–1000.
- Schell, Donald M., Bruce A. Barnett, and Kimberly A. Vinette
1998 Carbon and Nitrogen Isotope Ratios in Zooplankton of the Bering, Chukchi and Beaufort Seas. *Marine Ecology Progress Series* 162:11–23.
- Schell, Donald M., Victoria J. Rowntree, and Carl J. Pfeiffer
2000 Stable-Isotope and Electron-Microscopic Evidence that Cyamids (Crustacea: Amphipoda) Feed on Whale Skin. *Canadian Journal of Zoology* 78(5):721–727.
- Schoeninger, Margaret J.
1985 Trophic Level Effects on $^{15}\text{N}/^{14}\text{N}$ and $^{13}\text{C}/^{12}\text{C}$ Ratios in Bone Collagen and Strontium Levels in Bone Mineral. *Journal of Human Evolution* 14:515–525.
- Schoeninger, Margaret J., and Michael J. DeNiro
1984 Nitrogen and Carbon Isotopic Composition of Bone Collagen from Marine and Terrestrial Animals. *Geochimica et Cosmochimica Acta* 48:625–639.
- Schoeninger, Margaret J., Michael J. DeNiro, and Henrik Tauber
1983 Stable Nitrogen Isotope Ratios of Bone Collagen Reflect Marine and Terrestrial Components of Prehistoric Human Diet. *Science* 220:1381–1383.
- Schoeninger, Margaret J., and Katherine Moore
1992 Bone Stable Isotope Studies in Archaeology. *Journal of World Prehistory* 6:247–296.
- Schwarcz, Henry P., and Margaret J. Schoeninger
1991 Stable Isotope Analyses in Human Nutritional Ecology. *Yearbook of Physical Anthropology* 34:283–321.
- Selbie, Daniel T., Bert A. Lewis, John P. Smol, and Bruce P. Finney
2007 Long-Term Population Dynamics of the Endangered Snake River Sockeye Salmon: Evidence of Past Influences on Stock Decline and Impediments to Recovery. *Transactions of the American Fisheries Society* 136:800–821.
- Shahack-Gross, Ruth, Allison Simons, and Stanley H. Ambrose
2008 Identification of Pastoral Sites using Stable Nitrogen and Carbon Isotopes from Bulk Sediment Samples: A Case Study in Modern and Archaeological Pastoral Settlements in Kenya. *Journal of Archaeological Science* 35:983–990.
- Sharp, Zachary D.
2007 *Principles of Stable Isotope Geochemistry*. Pearson-Prentice Hall, Upper Saddle River, NJ.
- Terry, Richard E., Fabian G. Fernández, J. Jacob Parnell, and Takeshi Inomata
2004 The Story in the Floors: Chemical Signatures of Ancient and Modern Maya Activities at Aguateca, Guatemala. *Journal of Archaeological Science* 31:1237–1250.
- Toperoff, Amanda Kate
2002 Examination of Diet of Harbor Porpoise (*Phocoena phocoena*) from Central California Using Stomach Content and Stable Isotope Analysis from Multiple Tissues. Unpublished M.S. thesis, Moss Landing Marine Laboratories, San Jose State University, San Jose, CA.
- Tykot, R. H.
2006 Isotope Analyses and the Histories of Maize. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, edited by J. E. Staller, R. H. Tykot and B. F. Benz, pp. 131–142. Academic Press, New York.
- Uchiyama, T., B. P. Finney, and M. D. Adkison
2008 Effects of Marine-Derived Nutrients on Population Dynamics of Sockeye Salmon (*Oncorhynchus nerka*). *Canadian Journal of Fisheries and Aquatic Sciences* 65:1635–1648.
- Wada, E.
1980 Nitrogen Isotope Fractionation and Its Significance in Biogeochemical Processes Occurring in Marine

- Environments. In *Isotope Marine Chemistry*, edited by E.D. Goldberg, Y. Horibe, and K. Saruhashi, pp. 375–398. Uchida Rokahuko, Tokyo.
- Walker, Phillip L., and Michael J. DeNiro
1986 Stable Nitrogen and Carbon Isotope Ratios in Bone Collagen as Indices of Prehistoric Dietary Dependence on Marine and Terrestrial Resources in Southern California. *American Journal of Physical Anthropology* 71:51–61.
- Walkington, Helen
2010 Soil Science Applications in Archaeological Contexts: A Review of Key Challenges. *Earth-Science Reviews* 103:122–134.
- Wells, E. Christian
2004 Investigating Activity Patterns in Prehispanic Plazas: Weak-Acid Extraction ICP-AES Analysis of Anthrosols of Classic Period El Coyote, Northwestern Honduras. *Archaeometry* 46:67–84.
2010 Sampling Design and Inferential Bias in Archaeological Soil Chemistry. *Journal of Archaeological Method and Theory* 17:209–230.
- Wilkinson, Michael J., Youlim Yai, and Diane M. O'Brien
2007 Age-Related Variation in Red Blood Cell Stable Isotope Ratios ($\delta C-13$ and $\delta N-15$) from Two Yupik Villages in Southwest Alaska: A Pilot Study. *International Journal of Circumpolar Health* 66:31–41.
- Wilson, Clare A., Donald A. Davidson, and Malcolm S. Cresser
2008 Multi-Element Soil Analysis: An Assessment of Its Potential as an Aid to Archaeological Interpretation. *Journal of Archaeological Science* 35:412–424.
- Witteveen, Briana H., Graham A.J. Worthy, Kate M. Wynne, and James D. Roth
2009 Population Structure of North Pacific Humpback Whales on Their Feeding Grounds Revealed by Stable Carbon and Nitrogen Isotope Ratios. *Marine Ecology Progress Series* 379:299–310.
- Wooller, Matthew J., P.A.P. deHart, L. Quackenbush, and D. Vos
2005 Coupling Stable Isotope (C and N) Analysis of Stomach Contents and Tooth Collagen to Elucidate Patterns in a Transient Killer Whale's (*Orcinus orca*) Diet Composition. Paper presented at the Sixteenth Biennial Conference on the Biology of Marine Mammals, San Diego, CA, December, 2005.
- Worthy, Graham A.J.
2008 An Investigation into the Possible Relationship between Killer Whale (*Orcinus orca*) Predation and the Continuing Decline of the Steller Sea Lion (*Eumetopias jubatus*) Population. Final report to the Pollock Conservation Cooperative Research Center, University of Alaska Fairbanks.
- Wright, Lori E., and Henry P. Schwarcz
1999 Correspondence between Stable Carbon, Oxygen and Nitrogen Isotopes in Human Tooth Enamel and Dentine: Infant Diets at Kaminaljuyú. *Journal of Archaeological Science* 26:1159–1170.
- Yoneyama, T.
1996 Characterization of Natural ^{15}N of Soils. In *Mass Spectrometry of Soils*, edited by T.W. Boutton and S. Yamasaki, pp. 205–224. Marcel Dekker, Inc., New York.
- Youden, M. W., and A. Mehlich
1937 Selection of Efficient Methods for Soil Sampling. *Contributions of the Boyce Thompson Institute for Plant Research* 9:59–70.
- Young, Brent G., L. L. Loseto, and Steven H. Ferguson
2010 Diet Differences among Age Classes of Arctic Seals: Evidence from Stable Isotope and Mercury Biomarkers. *Polar Biology* 33(2):153–162.

APPENDIX 1. ARCTIC NITROGEN ISOTOPE DATA FROM PUBLISHED SOURCES

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Benthic Algae						
Periphyton (benthic algae)	algae	0.2	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	-0.1	1.0	2	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	-2.0	0.2	5	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.8	0.3	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.5	0.5	4	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.5	0.1	2	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.2	0.3	2	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.5	0.1	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.0	0.1	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.5	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.5	0.1	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.1	0.6	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	-0.5	0.2	2	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.9	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	2.2	0.1	4	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	1.4	0.2	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	6.2	0.4	3	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	6.3	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	0.6	0.2	4	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	2.4	0.1	2	Sashin Creek (AK, USA)	Kline et al. 1990
Periphyton (benthic algae)	algae	3.3	0.1	4	Sashin Creek (AK, USA)	Kline et al. 1990
Invertebrates						
Zooplankton	whole body	8.3	0.9	116	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (Copepods)	whole body	9.8	0.2	10	Barrow (AK, USA)	Hoekstra et al. 2002
Zooplankton (Copepods)	whole body	10.4	0.5	20	Kaktovik (AK, USA)	Hoekstra et al. 2002
Zooplankton (Copepods)	whole body	10.4	0.4	10	Holman (NW Territories, Canada)	Hoekstra et al. 2002
Zooplankton (Chaetognaths)	whole body	11.1	0.5	11	Arctic Ocean	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	11.9	0.6	15	Beaufort Sea (Canada)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	12.7	0.2	64	Central Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	12.9	0.3	35	East Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	12.3	0.3	27	East Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	12.3	0.8	4	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Chaetognaths)	whole body	12.8	0.8	11	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Chaetognaths)	whole body	13.5	0.6	5	Eastern Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	13.3	0.2	40	North Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	8.5	0.3	27	South Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	14.2	0.3	5	Western Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	11.6	0.3	27	West Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Chaetognaths)	whole body	12.2	0.3	26	West Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	9.0	1.1	36	Arctic Ocean	Schell et al. 1998
Zooplankton (Copepods)	whole body	10.0	0.2	14	Beaufort Sea (Canada)	Schell et al. 1998
Zooplankton (Copepods)	whole body	9.6	0.2	132	Central Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	9.8	0.2	64	East Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	10.5	0.2	54	East Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	10.3	0.6	33	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Copepods)	whole body	10.8	1.0	30	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Copepods)	whole body	10.8	0.2	45	Eastern Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	11.3	0.1	54	North Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	5.8	0.2	87	South Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	11.6	0.4	6	Western Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	8.7	0.2	64	West Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	whole body	10.3	0.3	54	West Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Copepods)	muscle	8.5	NA	1	Gulf of Alaska (AK, USA)	Hobson et al. 1997

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	n	Location	Reference
Zooplankton (Copepods; <i>Euchaeta elongata</i> or <i>Neocalanus</i> spp.)	whole body	12.0	0.2	6	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (Copepods; <i>Euchaeta elongata</i> or <i>Neocalanus</i> spp.)	whole body	11.9	0.6	23	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (Euphausiids)	whole body	9.3	0.2	47	Central Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	10.0	0.2	33	East Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	9.7	0.3	33	East Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	11.0	0.3	5	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Euphausiids)	whole body	11.2	0.7	5	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Zooplankton (Euphausiids)	whole body	11.0	0.2	36	North Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	7.2	0.3	34	South Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	9.1	0.2	32	West Bering Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	9.9	0.3	32	West Chukchi Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	9.2	0.6	18	Eastern Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids)	whole body	11.2	0.3	21	Western Beaufort Sea (AK, USA)	Schell et al. 1998
Zooplankton (Euphausiids; <i>Euphausia pacifica</i> and <i>Thysanoessa</i> spp.)	whole body	10.5	0.6	55	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (Euphausiids; <i>Euphausia pacifica</i> , <i>Thysanoessa</i> spp.)	whole body	9.4	0.3	20	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (Euphausiids; <i>Euphausia pacifica</i> , <i>Thysanoessa</i> spp.)	whole body	10.7	1.9	95	Prince William Sound (AK, USA)	Kline 1999
Zooplankton (<i>Neocalanus cristatus</i>)	whole body	8.0	1.8	938	Prince William Sound (AK, USA)	Kline et al. 1997
Crustaceans						
Amphipods (principally <i>Cyphocaris challengerii</i>)	whole body	11.6	0.8	23	Prince William Sound (AK, USA)	Kline 1999
Amphipods (principally <i>Cyphocaris challengerii</i>)	whole body	10.6	2.0	85	Prince William Sound (AK, USA)	Kline 1999
Aquatic sowbug (<i>Saduria entomon</i>)	whole body	10.1	NA	1	Bering Sea (AK, USA)	Dunton et al. 1989
Aquatic sowbug (<i>Saduria entomon</i>)	whole body	14.4	NA	1	Chukchi Sea (AK, USA)	Dunton et al. 1989
Aquatic sowbug (<i>Saduria entomon</i>)	whole body	10.9	0.7	3	Eastern Beaufort Sea (AK, USA)	Dunton et al. 1989
Decapods	whole body	11.2	1.9	20	Prince William Sound (AK, USA)	Kline 1999
Decapods	whole body	11.4	1.5	38	Prince William Sound (AK, USA)	Kline 1999
Hermit crab (<i>Pagurus trigonochirus</i>)	muscle	12.0	0.2	2	Bering Sea (AK, USA)	Dunton et al. 1989
Hermit crab (<i>Pagurus trigonochirus</i>)	muscle	11.9	NA	1	Chukchi Sea (AK, USA)	Dunton et al. 1989
Hermit crab (<i>Pagurus trigonochirus</i>)	muscle	12.0	NA	1	Western Beaufort Sea (AK, USA)	Dunton et al. 1989
Shrimp (<i>Crangon dalli</i>)	whole body	14.4	0.4	2	Bering Sea (AK, USA)	Dunton et al. 1989
Molluscs						
Mollusc (<i>Hiatella arctica</i>)	whole body	9.1	0.7	5	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Squid (<i>Berryteuthis magister</i>)	whole body	11.4	0.2	3	Bering Sea (AK, USA)	Kurle & Worthy 2001
Squid (<i>Berryteuthis magister</i>)	whole body	11.4	0.2	9	Bering Sea (AK, USA)	Kurle & Worthy 2001
Squid (<i>Berryteuthis magister</i>)	NA	12.3	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Squid (<i>Berryteuthis magister</i>)	NA	14.1	NA	NA	Shelikof Strait (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Squid (<i>Gonatopsis borealis</i>)	whole body	11.1	0.2	3	Bering Sea (AK, USA)	Kurle & Worthy 2001
Squid (<i>Gonatopsis borealis</i>)	NA	9.7	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Squid	muscle	16.7	NA	1	Gulf of Alaska (AK, USA)	Hobson et al. 1997
Squid	muscle	9.6	0.5	4	Gulf of Alaska (AK, USA)	Hobson et al. 1997

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Anadromous Fish						
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	NA	13.8	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	muscle	14.0	0.6	6	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	NA	14.9	NA	NA	Shelikof Strait (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	bone	13.2	NA	1	Yukon River (AK, USA)	Misarti 2007
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	muscle	14.4	NA	1	Yukon River (AK, USA)	Misarti 2007
Chum salmon (<i>Oncorhynchus keta</i>)	muscle	11.8	0.2	3	Barrow (AK, USA)	Hoekstra et al. 2002
Chum salmon (<i>Oncorhynchus keta</i>)	whole body	10.5	NA	1	Bering Sea (AK, USA)	Kurle & Worthy 2001
Chum salmon (<i>Oncorhynchus keta</i>)	muscle	10.6	1.1	39	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Chum salmon (<i>Oncorhynchus keta</i>)	muscle	11.0	1.2	25	AK, USA	Satterfield & Finney 2002
Coho salmon (<i>Oncorhynchus kisutch</i>)	muscle	11.8	0.7	39	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Coho salmon (<i>Oncorhynchus kisutch</i>)	muscle	13.8	0.5	12	AK, USA	Satterfield & Finney 2002
Coho salmon (<i>Oncorhynchus kisutch</i>), spawning	whole body	9.0	NA	2	Sashin Creek (AK, USA)	Kline et al. 1990
Coho salmon (<i>Oncorhynchus kisutch</i>), spawning	whole body	12.0	NA	3	Sashin Creek (AK, USA)	Kline et al. 1990
Coho salmon (<i>Oncorhynchus kisutch</i>), spawning	whole body	11.4	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Coho salmon (<i>Oncorhynchus kisutch</i>), spawning	whole body	13.5	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Dolly Varden trout (<i>Salvelinus malma</i>), spawning	whole body	10.9	NA	2	Sashin Creek (AK, USA)	Kline et al. 1990
Dolly Varden trout (<i>Salvelinus malma</i>), spawning	whole body	13.5	NA	3	Sashin Creek (AK, USA)	Kline et al. 1990
Dolly Varden trout (<i>Salvelinus malma</i>), spawning	whole body	12.2	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
Dolly Varden trout (<i>Salvelinus malma</i>), spawning	whole body	12.9	NA	1	Sashin Creek (AK, USA)	Kline et al. 1990
King salmon (<i>Oncorhynchus tshawytscha</i>)	muscle	15.2	0.3	15	AK, USA	Satterfield & Finney 2002
Pink salmon (<i>Oncorhynchus gorbuscha</i>)	muscle	10.8	0.6	7	Barrow (AK, USA)	Hoekstra et al. 2002
Pink salmon (<i>Oncorhynchus gorbuscha</i>)	NA	8.5	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pink salmon (<i>Oncorhynchus gorbuscha</i>)	muscle	10.4	1.0	37	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Pink salmon (<i>Oncorhynchus gorbuscha</i>)	muscle	10.8	0.4	22	AK, USA	Satterfield & Finney 2002
Silver salmon (<i>Oncorhynchus kisutch</i>)	NA	15.0	NA	NA	Shelikof Strait (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	bone	11.5	1.7	91	Sanak Islands (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	bone	9.5	0.3	3	Chitina River (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.2	0.5	3	Chitina River (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	11.4	0.7	40	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Sockeye salmon (<i>Oncorhynchus nerka</i>)	bone	9.0	NA	1	Kodiak (AK, USA)	Misarti 2007

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.3	NA	1	Kodiak (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	whole body	11.6	0.3	4	Kvichak River (AK, USA)	Kline et al. 1993
Sockeye salmon (<i>Oncorhynchus nerka</i>)	whole body	12.3	0.9	16	Tazimina River and Chinkelyes Creek (AK, USA)	Kline et al. 1993
Sockeye salmon (<i>Oncorhynchus nerka</i>)	bone	10.5	1.0	2	Unalaska (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.7	0.2	2	Unalaska (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	bone	9.2	NA	1	Yukon River (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.9	NA	1	Yukon River (AK, USA)	Misarti 2007
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	11.2	0.6	47	AK, USA	Satterfield & Finney 2002
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	11.0	0.6	29	AK, USA	Satterfield & Finney 2002
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.6	NA	32	Black Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.4	NA	34	Iliamna Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.7	NA	50	Iliamna Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.0	NA	60	Iliamna Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	13.7	NA	5	Akalura Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	12.6	NA	10	Auke Lake, Juneau (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.1	NA	15	Becharof Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.5	NA	24	Becharof Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	7.5	NA	19	Becharof Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.3	NA	68	Black Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.9	NA	6	Chignik Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.8	NA	50	Chignik Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.0	NA	29	Chignik Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.9	NA	20	Chignik Lake (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	13.0	NA	10	Chilkat Lake (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	13.4	NA	10	Chilkat Lake (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.5	NA	10	Chilkoot Lake (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.1	NA	20	Coghill Lake, Prince William Sound (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	12.6	NA	5	Frazer Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.1	NA	20	Frazer Lake, Kodiak (AK, USA)	Uchiyama et al. 2008

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	10.8	NA	20	Hidden Lake, Cook Inlet (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.4	NA	10	Hugh Smith Lake (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.7	NA	5	Iliamna Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	12.8	NA	7	Karluk Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	15.7	NA	12	Karluk Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	14.0	NA	18	Karluk Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	13.2	NA	19	Karluk Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	11.0	NA	10	Lake McDonald (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	16.1	NA	20	Red Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	7.7	NA	10	Redoubt Lake, Southeast (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	7.1	NA	10	Speel Lake, Southeast (AK, USA)	Barto 2004; in Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	11.3	NA	10	Spiridon Lake, Kodiak (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.6	NA	19	Tustumena Lake, Cook Inlet (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.5	NA	16	Ugashik Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.6	NA	25	Ugashik Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	9.8	NA	20	Ugashik Lake, Bristol Bay (AK, USA)	Uchiyama et al. 2008
Sockeye salmon (<i>Oncorhynchus nerka</i>)	muscle	8.1	NA	20	Upper Russian Lake, Cook Inlet (AK, USA)	Uchiyama et al. 2008
Steelhead trout (<i>Oncorhynchus mykiss</i>)	muscle	12.5	1.0	35	Gulf of Alaska (AK, USA)	Kaeriyama et al. 2004
Marine Fish						
Pacific herring (<i>Clupea pallasii</i>)	whole body	15.3	0.2	5	Bering Sea (AK, USA)	Kurle & Worthy 2001
Pacific herring (<i>Clupea pallasii</i>)	whole body	13.5	0.1	8	Bering Sea (AK, USA)	Kurle & Worthy 2001
Pacific herring (<i>Clupea pallasii</i>)	NA	13.9	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pacific herring (<i>Clupea pallasii</i>)	NA	14.5	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pacific herring (<i>Clupea pallasii</i>)	whole body	12.3	0.9	110	Prince William Sound (AK, USA)	Kline 1999
Pacific herring (<i>Clupea pallasii</i>)	whole body	12.7	0.3	250	Prince William Sound (AK, USA)	Kline 1999
Pacific cod (<i>Gadus macrocephalus</i>)	bone	16.1	1.2	101	Sanak Islands (AK, USA)	Misarti 2007
Pacific cod (<i>Gadus macrocephalus</i>)	NA	17.9	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pacific cod (<i>Gadus macrocephalus</i>)	NA	14.8	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pacific cod (<i>Gadus macrocephalus</i>)	NA	17.1	NA	NA	Bering Sea (AK, USA)	Kurle et al. unpub. data in Worthy 2008
Pacific cod (<i>Gadus macrocephalus</i>)	muscle	16.2	1.3	3	Bering Sea (AK, USA)	Dunton et al. 1989
Pacific cod (<i>Gadus macrocephalus</i>)	muscle	11.4	0.2	19	Gulf of Alaska (AK, USA)	Hobson et al. 1997
Pacific cod (<i>Gadus macrocephalus</i>)	bone	16.6	NA	1	Pavlof (AK, USA)	Misarti 2007
Pacific cod (<i>Gadus macrocephalus</i>)	muscle	17.1	NA	1	Pavlof (AK, USA)	Misarti 2007
Pacific cod (<i>Gadus macrocephalus</i>)	NA	17.9	NA	NA	Shelikof Strait (AK, USA)	Kurle et al. unpub. data in Worthy 2008

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Sea birds						
Ancient murrelet (<i>Synthliboramphus antiquus</i>)	muscle	15.0	0.3	12	Oak Bay (BC, Canada)	Hobson et al. 1994
Ancient murrelet (<i>Synthliboramphus antiquus</i>)	muscle	12.8	0.6	5	Shumagin Islands, Alaska	Hobson et al. 1994
Black guillemot (<i>Cepphus grylle</i>)	muscle	15.0	0.4	6	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Black guillemot (<i>Cepphus grylle</i>)	bone	18.2	0.7	16	Lancaster Sound (Nunavut, Canada)	Hobson & Montevecchi 1991
Black-legged kittiwake (<i>Rissa tridactyla</i>)	muscle	15.8	0.3	6	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Black-legged kittiwake (<i>Rissa tridactyla</i>)	muscle	14.2	1.1	6	Shumagin Islands (AK, USA)	Hobson et al. 1994
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	muscle	14.5	0.2	6	Barkley Sound (BC, Canada)	Hobson et al. 1994
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	bone	16.4	0.2	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	muscle	12.3	0.5	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	muscle	13.5	0.4	6	Shumagin Islands (AK, USA)	Hobson et al. 1994
Common eider (<i>Somateria mollissima</i>)	muscle	13.5	0.0	3	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Common murre (<i>Uria aalge</i>)	bone	17.3	0.8	6	Masset Inlet (BC, Canada)	Hobson et al. 1994
Common murre (<i>Uria aalge</i>)	muscle	15.5	1.3	6	Masset Inlet (BC, Canada)	Hobson et al. 1994
Common murre (<i>Uria aalge</i>)	muscle	15.3	0.9	5	Shumagin Islands (AK, USA)	Hobson et al. 1994
Crested auklet (<i>Aethia cristatella</i>)	feathers	14.5	2.3	13	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Crested auklet (<i>Aethia cristatella</i>)	feathers	13.5	2.3	9	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Crested auklet (<i>Aethia cristatella</i>)	feathers	12.6	2.0	9	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Crested auklet (<i>Aethia cristatella</i>)	feathers	12.6	1.9	6	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Crested auklet (<i>Aethia cristatella</i>)	muscle	12.5	0.7	6	Shumagin Islands (AK, USA)	Hobson et al. 1994
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	muscle	17.5	NA	1	Shumagin Islands (AK, USA)	Hobson et al. 1994
Fork-tailed storm-petrel (<i>Oceanodroma furcata</i>)	bone	17.9	0.4	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Fork-tailed storm-petrel (<i>Oceanodroma furcata</i>)	muscle	15.9	0.4	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Fork-tailed storm-petrel (<i>Oceanodroma furcata</i>)	muscle	14.0	NA	1	Semidi Islands (AK, USA)	Hobson et al. 1994
Glaucous gull (<i>Larus hyperboreus</i>)	muscle	16.7	0.2	4	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Glaucous-winged gull (<i>Larus canus</i>)	muscle	15.1	0.9	6	Shumagin Islands (AK, USA)	Hobson et al. 1994
Great auk (<i>Pinguinus impennis</i>)	bone	15.8	1.9	30	Funk Island (Newfoundland, Canada)	Hobson & Montevecchi 1991
Horned puffin (<i>Fratercula corniculata</i>)	muscle	13.3	0.8	4	Shumagin Islands (AK, USA)	Hobson et al. 1994
Kittlitz's murrelet (<i>Brachyramphus brevirostris</i>)	muscle	14.5	1.1	6	Kachemak Bay (AK, USA)	Hobson et al. 1994
Leach's storm-petrel (<i>Oceanodroma leucorhoa</i>)	bone	17.1	0.3	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Leach's storm-petrel (<i>Oceanodroma leucorhoa</i>)	muscle	13.5	0.9	6	Hippa Island (BC, Canada)	Hobson et al. 1994
Leach's storm-petrel (<i>Oceanodroma leucorhoa</i>)	muscle	13.8	0.7	5	Semidi Islands (AK, USA)	Hobson et al. 1994
Little auk or dovekie (<i>Alle alle</i>)	muscle	12.5	NA	1	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	muscle	15.3	0.2	19	Barkley Sound (BC, Canada)	Hobson et al. 1994
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	muscle	14.7	0.6	10	Kachemak Bay (AK, USA)	Hobson et al. 1994
Mew gull (<i>Larus canus</i>)	muscle	15.3	0.4	3	Shumagin Islands (AK, USA)	Hobson et al. 1994
Northern fulmar (<i>Fulmarus glacialis</i>)	muscle	15.4	0.2	5	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Northern fulmar (<i>Fulmarus glacialis</i>)	muscle	15.7	1.0	5	Shumagin Islands (AK, USA)	Hobson et al. 1994
Parakeet auklet (<i>Aethia psittacula</i>)	muscle	13.8	0.4	5	Shumagin Islands (AK, USA)	Hobson et al. 1994
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	muscle	15.8	1.1	3	Shumagin Islands (AK, USA)	Hobson et al. 1994
Pigeon guillemot (<i>Cephus columba</i>)	muscle	16.5	0.2	5	Barkley Sound (BC, Canada)	Hobson et al. 1994
Pigeon guillemot (<i>Cephus columba</i>)	muscle	15.1	0.7	4	Shumagin Islands (AK, USA)	Hobson et al. 1994
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	muscle	15.9	0.2	9	Barkley Sound (BC, Canada)	Hobson et al. 1994
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	bone	17.6	0.4	6	Lucy Island (BC, Canada)	Hobson et al. 1994
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	muscle	15.4	0.5	6	Lucy Island (BC, Canada)	Hobson et al. 1994
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	muscle	13.1	1.2	2	Semidi Islands (AK, USA)	Hobson et al. 1994
Sooty shearwater (<i>Puffinus griseus</i>)	bone	15.8	0.4	4	Hecate Strait (BC, Canada)	Hobson et al. 1994
Sooty shearwater (<i>Puffinus griseus</i>)	muscle	11.7	0.9	4	Hecate Strait (BC, Canada)	Hobson et al. 1994
Surf scoter (<i>Melanitta perspicillata</i>)	bone	11.8	1.0	5	Hecate Strait (BC, Canada)	Hobson et al. 1994
Thick-billed murre (<i>Uria lomvia</i>)	muscle	16.4	0.1	4	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Thick-billed murre (<i>Uria lomvia</i>)	bone	17.6	1.1	14	Lancaster Sound (Nunavut, Canada)	Hobson & Montevecchi 1991
Tufted puffin (<i>Fratercula cirrhata</i>)	muscle	12.9	0.5	4	Shumagin Islands (AK, USA)	Hobson et al. 1994
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	15.5	1.4	15	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	15.4	1.4	15	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	16.0	1.4	3	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	15.5	1.1	3	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	13.4	2.5	32	North Pacific	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	13.4	2.5	21	North Pacific	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	12.1	1.9	3	North Pacific	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	13.2	1.8	17	North Pacific	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	feathers	12.5	2.3	14	North Pacific	Hobson, Sinclair et al. 2004
Tufted puffin (<i>Fratercula cirrhata</i>)	muscle	14.7	0.5	5	Triangle Island (BC, Canada)	Hobson et al. 1994
White-winged scoter (<i>Melanitta fusca</i>)	bone	12.2	0.4	5	Hecate Strait (BC, Canada)	Hobson et al. 1994
Marine Mammals (Order: Cetacea)						
Blue whale (<i>Balaenoptera musculus</i>)	skin	12.9	0.3	2	Bahia de La Paz (Mexico)	Gendron et al. 2001
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.3	0.6	110	AK, USA	Dehn et al. 2006
Bowhead whale (<i>Balaena mysticetus</i>)	skin	13.9	0.2	2	AK, USA	Schell et al. 2000
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.3	0.3	21	Barrow (AK, USA)	Hoekstra et al. 2002

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.5	0.4	9	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.1	0.2	16	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.3	0.3	15	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	12.5	0.3	5	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	12.9	0.6	4	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.1	0.2	2	Barrow (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.4	0.7	122	Barrow (AK, USA)	Dehn et al. 2006; includes data from Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.2	0.7	24	Eastern Beaufort Sea (AK, USA)	Lee et al. 2005
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	14.3	0.8	18	Eastern Beaufort Sea (AK, USA)	Schell 1992 in Lee et al. 2005
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.1	0.2	4	Kaktovik (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	12.8	0.4	3	Kaktovik (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.6	0.6	3	Kaktovik (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	muscle	13.5	0.9	2	Kaktovik (AK, USA)	Hoekstra et al. 2002
Bowhead whale (<i>Balaena mysticetus</i>)	baleen	14.4	0.8	71	Western Arctic Sea	Hobson & Schell 1998
Bryde's whale (<i>Balaenoptera edeni</i>)	skin	15.8	0.6	2	Bahia de la Paz (Mexico)	Gendron et al. 2001
Fin whale (<i>Balaenoptera physalus</i>)	skin	15.4	1.1	2	Bahia de la Paz (Mexico)	Gendron et al. 2001
Gray whale (<i>Eschrichtius robustus</i>)	baleen	15.1	0.1	2	Baja California Sur (Mexico)	Caraveo-Patino et al. 2007
Gray whale (<i>Eschrichtius robustus</i>)	baleen	13.5	0.5	4	Baja California Sur (Mexico)	Caraveo-Patino et al. 2007
Gray whale (<i>Eschrichtius robustus</i>)	skin	14.2	0.7	4	Bering Sea, Chukchi Sea (AK, USA)	Schell et al. 2000
Gray whale (<i>Eschrichtius robustus</i>)	muscle	12.0	0.9	17	Russia	Dehn et al. 2006
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	12.4	0.1	122	Bering Sea (AK, USA)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	14.7	0.1	128	CA and OR, USA	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	12.1	0.2	56	Eastern Aleutian Islands (AK, USA)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	13.0	0.1	135	Pacific Ocean (BC, Canada)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	13.6	0.1	199	Gulf of Alaska (AK, USA)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	12.5	0.2	67	Russia	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	12.7	0.1	227	Pacific Ocean (AK, USA)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	14.6	0.1	53	Pacific Ocean (BC, Canada)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	11.4	0.3	14	Western Aleutian Islands (AK, USA)	Witteveen et al. 2009
Humpback whale (<i>Megaptera novaeangliae</i>)	skin	13.1	0.1	104	Gulf of Alaska (AK, USA)	Witteveen et al. 2009
Beluga whale (<i>Delphinapterus leucas</i>)	muscle	16.7	0.6	49	AK, USA	Dehn et al. 2006
Beluga whale (<i>Delphinapterus leucas</i>)	muscle	16.6	0.6	6	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Beluga whale (<i>Delphinapterus leucas</i>)	muscle	16.4	0.3	4	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Beluga whale (<i>Delphinapterus leucas</i>)	muscle	16.6	0.1	22	Point Lay (AK, USA)	Hoekstra et al. 2002
Dall's porpoise (<i>Phocoenoides dalli</i>)	NA	11.5	NA	NA	Bering Sea (AK, USA)	Ohizumi & Miyazaki 2001 in Worthy 2008
Dall's porpoise (<i>Phocoenoides dalli</i>)	NA	12.3	NA	NA	Gulf of Alaska (AK, USA)	Hirons unpub. data in Worthy 2008
Harbor porpoise (<i>Phocoena phocoena</i>)	bone	15.7	0.7	29	Monterey Bay (CA, USA)	Toporoff 2002

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Harbor porpoise (<i>Phocoena phocoena</i>)	muscle	15.2	0.8	29	Monterey Bay (CA, USA)	Toperoff 2002
Harbor porpoise (<i>Phocoena phocoena</i>)	skin	16.0	0.7	29	Monterey Bay (CA, USA)	Toperoff 2002
Killer whale (<i>Orcinus orca</i>), offshore	blubber	17.2	0.6	3	AK, USA	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), offshore	blubber	16.8	0.3	2	Trinity Island, Gulf of Alaska (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), resident	blubber	17.9	NA	1	Aleutian Islands (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), resident	blubber	15.6	1.5	11	Central Aleutian Islands (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), resident	blubber	15.1	0.9	2	Central Aleutian Islands (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), resident	blubber	16.7	1.2	11	Eastern Aleutian Islands (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), resident	blubber	16.0	1.1	5	Eastern Aleutian Islands (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), resident	blubber	17.2	0.8	8	Gulf of Alaska (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), resident	blubber	21.0	NA	1	Gulf of Alaska (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), resident	blubber	17.8	1.0	20	Prince William Sound (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), resident	blubber	17.9	0.5	4	Trinity Island, Gulf of Alaska (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), southern resident	blubber	16.9	0.6	4	Pacific Ocean	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	18.7	1.8	2	Central Aleutian Islands (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	17.9	0.5	9	Eastern Aleutian Islands (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	17.8	0.2	2	Aleutian Islands (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), transient	blubber	19.8	NA	1	Gulf of Alaska (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	17.8	1.0	2	Gulf of Alaska (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), transient	blubber	18.3	1.0	9	Prince William Sound (AK, USA)	Worthy 2008
Killer whale (<i>Orcinus orca</i>), transient	blubber	20.0	0.8	2	Prince William Sound (AK, USA)	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	17.6	NA	1	Pacific Ocean	Herman et al. 2005
Killer whale (<i>Orcinus orca</i>), transient	blubber	21.2	NA	1	Pacific Ocean	Herman et al. 2005
Minke whale (<i>Balaenoptera acutorostrata</i>)	muscle	12.2	1.0	43	Western North Atlantic (Greenland)	Born et al. 2003
Narwhal (<i>Monodon monoceros</i>)	muscle	15.8	0.7	4	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Narwhal (<i>Monodon monoceros</i>)	muscle	15.9	NA	2	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Marine Mammals (Order: Carnivora)						
Sea otter (<i>Enhydra lutris</i>)	NA	14.7	NA	NA	Aleutian Islands (AK, USA)	Hirons unpub. data in Worthy 2008
Sea otter (<i>Enhydra lutris</i>)	NA	13.6	NA	NA	Prince William Sound (AK, USA)	Hirons unpub. data in Worthy 2008
Sea otter (<i>Enhydra lutris</i>)	NA	18.3	NA	NA	Prince William Sound (AK, USA)	Wooler et al. 2005, in Worthy 2008
Sea otter (<i>Enhydra lutris</i>)	bone	14.5	1.4	88	Sanak Islands (AK, USA)	Misarti 2007
Walrus (<i>Odobenus rosmarus</i>)	muscle	12.5	0.6	6	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Walrus (<i>Odobenus rosmarus</i>)	muscle	13.5	1.0	6	Barrow (AK, USA)	Dehn et al. 2006
Walrus (<i>Odobenus rosmarus</i>)	muscle	12.8	0.4	3	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Bearded seal (<i>Erignathus barbatus</i>)	muscle	16.8	0.2	4	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Bearded seal (<i>Erignathus barbatus</i>)	muscle	16.7	0.9	47	Barrow (AK, USA)	Dehn et al. 2005
Bearded seal (<i>Erignathus barbatus</i>)	muscle	16.8	0.4	6	Barrow (AK, USA)	Hoekstra et al. 2002
Bearded seal (<i>Erignathus barbatus</i>)	muscle	16.8	0.5	4	Hudson Bay (Canada)	Young et al. 2010
Bearded seal (<i>Erignathus barbatus</i>)	muscle	15.7	1.2	2	Hudson Bay (Canada)	Young et al. 2010
Bearded seal (<i>Erignathus barbatus</i>)	muscle	14.5	0.3	6	Hudson Bay (Canada)	Young et al. 2010
Gray seal (<i>Halichoerus grypus</i>)	serum	16.2	0.3	2	Quebec Aquarium (Quebec, Canada)	Lesage et al. 2002

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Gray seal (<i>Halichoerus grypus</i>)	serum	16.7	0.2	5	University of Guelph (Ontario, Canada)	Lesage et al. 2002
Harbor seal (<i>Phoca vitulina</i>)	bone	17.1	1.7	37	Sanak Islands (AK, USA)	Misarti 2007
Harbor seal (<i>Phoca vitulina</i>)	bone	16.7	2.1	17	AK, USA	Burton & Koch 1999
Harbor seal (<i>Phoca vitulina</i>)	bone	18.0	1.2	20	AK, USA	Burton & Koch 1999
Harbor seal (<i>Phoca vitulina</i>)	NA	19.9	NA	NA	Aleutian Islands (AK, USA)	Hirons unpub. data in Worthy 2008
Harbor seal (<i>Phoca vitulina</i>)	bone	18.0	2.2	9	Bering Sea (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	14.8	0.8	2	Bering Sea (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	16.5	0.2	2	Bering Sea (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	18.4	0.6	2	Bering Sea (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	17.5	1.4	8	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	20.2	0.0	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	17.9	1.4	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	17.3	0.2	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	16.9	0.3	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	16.4	1.2	3	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	16.2	0.6	5	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	muscle	18.6	0.3	9	Copper River Delta (AK, USA)	Hobson et al. 1997
Harbor seal (<i>Phoca vitulina</i>)	muscle	16.3	0.3	10	Hudson Bay (Canada)	Young et al. 2010
Harbor seal (<i>Phoca vitulina</i>)	muscle	16.3	0.5	4	Hudson Bay (Canada)	Young et al. 2010
Harbor seal (<i>Phoca vitulina</i>)	muscle	17.2	0.1	2	Hudson Bay (Canada)	Young et al. 2010
Harbor seal (<i>Phoca vitulina</i>)	NA	16.5	NA	NA	Prince William Sound (AK, USA)	Hirons unpub. data in Worthy 2008
Harbor seal (<i>Phoca vitulina</i>)	NA	16.4	NA	NA	Prince William Sound (AK, USA)	Wooler et al. 2005 in Worthy 2008
Harbor seal (<i>Phoca vitulina</i>)	serum	16.0	0.4	3	Quebec Aquarium (Quebec, Canada)	Lesage et al. 2002
Harbor seal (<i>Phoca vitulina</i>)	serum	15.6	0.3	4	Shippagan (New Brunswick, Canada)	Lesage et al. 2002
Harbor seal (<i>Phoca vitulina</i>)	bone	15.8	NA	1	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	19.0	1.4	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	bone	16.4	0.7	5	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harbor seal (<i>Phoca vitulina</i>)	serum	16.6	0.2	3	University of Guelph (Ontario, Canada)	Lesage et al. 2002
Harbor seal (<i>Phoca vitulina</i>)	bone	17.1	1.2	8	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Harp seal (<i>Phoca groenlandica</i>)	serum	17.4	0.3	8	Memorial University (Newfoundland, Canada)	Lesage et al. 2002
Northern elephant seal (<i>Mirounga angustirostris</i>)	bone	18.2	0.7	10	CA, USA	Burton & Koch 1999
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	16.1	2.4	27	Sanak Islands (AK, USA)	Misarti 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	17.6	1.3	10	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	15.7	1.1	55	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	15.3	1.0	30	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	15.6	0.9	50	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	15.3	0.9	35	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	dentine	15.7	1.2	40	Saint Paul Island (AK, USA)	Newsome et al. 2007
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	17.4	2.1	9	AK, USA	Burton & Koch 1999
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	16.6	1.4	10	AK, USA	Burton & Koch 1999
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	17.6	1.8	13	Bering Sea (AK, USA)	Hirons et al. 2001

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	16.1	0.8	2	Bering Sea (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	20.3	0.9	2	Bering Sea (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	18.9	1.6	2	Bering Sea (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	18.9	1.5	5	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	18.0	0.6	3	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	muscle	16.6	0.5	7	Pribilof Islands (AK, USA)	Hobson et al. 1997
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	17.3	0.1	46	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	16.7	0.1	28	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	18.1	0.1	3	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	fur	14.8	0.1	28	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	muscle	15.6	0.2	30	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	brain	16.9	0.1	29	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	17.1	0.1	30	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	16.0	0.2	17	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	liver	16.0	0.2	30	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	kidney	16.3	0.2	26	St. George Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	17.3	0.1	46	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	16.5	0.2	20	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	15.6	0.2	5	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	17.4	0.3	11	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	skin	18.1	0.2	15	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	fur	14.9	0.2	39	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	muscle	15.1	0.2	38	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	brain	17.0	0.1	39	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	17.1	0.1	36	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	15.8	0.2	31	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	liver	16.2	0.1	40	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	kidney	16.4	0.2	37	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	fur	16.3	0.8	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Northern fur seal (<i>Callorhinus ursinus</i>)	fur	17.4	NA	1	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	muscle	16.1	0.5	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	muscle	16.1	0.3	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	brain	17.9	0.1	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	brain	17.7	0.2	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	18.0	0.4	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	18.9	NA	1	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	16.5	0.6	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	blubber	18.3	NA	1	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	liver	17.6	0.0	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	liver	16.8	0.1	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	kidney	16.9	0.2	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	kidney	17.0	0.5	2	St. Paul Island (Pribilof Islands) (AK, USA)	Kurle & Worthy 2002
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	18.2	1.3	4	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Northern fur seal (<i>Callorhinus ursinus</i>)	bone	18.5	0.4	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Polar bear (<i>Ursus maritimus</i>)	muscle	21.1	0.6	3	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Polar bear (<i>Ursus maritimus</i>)	muscle	20.6	0.6	10	Barrow (AK, USA), Alaska	Dehn et al. 2006
Polar bear (<i>Ursus maritimus</i>)	muscle	19.6	0.5	5	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Ringed seal (<i>Pusa hispida</i>)	muscle	17.3	1.1	9	Lancaster Sound (Nunavut, Canada)	Hobson & Welch 1992
Ringed seal (<i>Pusa hispida</i>)	muscle	16.9	0.6	78	Barrow (AK, USA), Alaska	Dehn et al. 2005
Ringed seal (<i>Pusa hispida</i>)	muscle	16.9	0.2	33	Barrow (AK, USA), Alaska	Hoekstra et al. 2002
Ringed seal (<i>Pusa hispida</i>)	muscle	17.2	0.7	25	Holman (NW Territories, Canada)	Dehn et al. 2005
Ringed seal (<i>Pusa hispida</i>)	muscle	12.9	0.3	9	Hudson Bay (Canada)	Young et al. 2010
Ringed seal (<i>Pusa hispida</i>)	muscle	13.8	0.3	4	Hudson Bay (Canada)	Young et al. 2010
Ringed seal (<i>Pusa hispida</i>)	muscle	14.6	0.3	3	Hudson Bay (Canada)	Young et al. 2010
Ringed seal (<i>Pusa hispida</i>)	muscle	16.4	0.2	20	Lancaster Sound (Nunavut, Canada)	Atwell et al. 1998
Spotted seal (<i>Phoca largha</i>)	muscle	17.6	0.9	34	Little Diomed and Shishmaref (AK, USA)	Dehn et al. 2005
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	18.4	1.4	15	Sanak Islands (AK, USA)	Misarti 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	17.0	NA	1	Bering Sea (AK, USA)	Hirons et al. 2001
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	18.1	1.9	2	Bering Sea (AK, USA)	Hirons et al. 2001
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	18.0	0.1	2	Bering Sea (AK, USA)	Hirons et al. 2001
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	18.7	0.8	3	Bering Sea (AK, USA)	Hirons et al. 2001
Steller sea lion (<i>Eumetopias jubatus</i>)	red blood cells	15.6	0.2	5	Central Aleutian Islands (AK, USA)	Kurle & Gudmundson 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	serum	16.4	0.3	5	Central Aleutian Islands (AK, USA)	Kurle & Gudmundson 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	18.5	NA	1	Gulf of Alaska (AK, USA)	Hirons et al. 2001
Steller sea lion (<i>Eumetopias jubatus</i>)	red blood cells	17.8	0.7	5	Eastern Aleutian Islands (AK, USA)	Kurle & Gudmundson 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	serum	19.0	0.9	5	Eastern Aleutian Islands (AK, USA)	Kurle & Gudmundson 2007

Species	Sample type	$\delta^{15}\text{N}$ (‰)	standard error / standard deviation	<i>n</i>	Location	Reference
Steller sea lion (<i>Eumetopias jubatus</i>)	enamel	18.7	0.5	113	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Steller sea lion (<i>Eumetopias jubatus</i>)	enamel	18.1	0.7	113	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Steller sea lion (<i>Eumetopias jubatus</i>)	enamel	17.6	0.6	113	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Steller sea lion (<i>Eumetopias jubatus</i>)	enamel	17.5	0.7	107	Gulf of Alaska (AK, USA)	Hobson, Sinclair et al. 2004
Steller sea lion (<i>Eumetopias jubatus</i>)	red blood cells	17.9	0.1	11	Gulf of Alaska (AK, USA)	Kurle & Gudmundson 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	serum	19.3	0.2	11	Gulf of Alaska (AK, USA)	Kurle & Gudmundson 2007
Steller sea lion (<i>Eumetopias jubatus</i>)	muscle	17.5	0.2	13	Copper River Delta (AK, USA)	Hobson et al. 1997
Steller sea lion (<i>Eumetopias jubatus</i>)	bone	17.4	0.6	2	Gulf of Alaska (AK, USA)	Hirons et al. 2001

THE FAUNAL ASSEMBLAGE FROM AWA'UQ (REFUGE ROCK): A UNIQUE RECORD FROM THE KODIAK ARCHIPELAGO, ALASKA

Michael A. Etnier

Department of Anthropology, Western Washington University, Bellingham, WA 98225; michael.etnier@wwu.edu

ABSTRACT

The *Awa'uq*, or Refuge Rock site (KOD-450), located on Sitkalidak Island in the southern Kodiak Archipelago (hereafter, Kodiak), is well known as the site of a brutal massacre in 1784. Less appreciated is the fact that twenty-eight house pits and a well-preserved faunal midden were documented at the site in the 1990s. The midden sample is dominated by northern fur seal (*Callorhinus ursinus*), and large cod (*Gadus macrocephalus*) and halibut (*Hippoglossus stenolepis*). Fur seal is a common component of late prehistoric sites in southern Kodiak, but typically in conjunction with harbor seal (*Phoca vitulina*). Unlike other Kodiak samples, harbor seal is virtually absent from the *Awa'uq* sample. Bird remains are scarce, but show a high diversity of species. Fish remains also show a broad spectrum of species ranging from herring (*Clupea pallasii*) to sculpins (Cottidae) to cod, in addition to the large halibut. The fur seal harvest focused on adult females and sub-adult males, with low frequencies of fetal individuals and adult males present. No rookery-age fur seal pups have been identified. This suggests the hunt was conducted at sea and focused on fur seals migrating to and from rookeries in the Bering Sea, rather than on a local rookery not documented historically.

The *Awa'uq* site (also known as Refuge Rock, KOD-450), on the southeastern shore of Sitkalidak Island, adjacent to Kodiak Island (Figs. 1, 2), is infamous as the location where hundreds of Alutiiq villagers were held under siege and later massacred by Grigori Shelikhov and his men in August, 1784 (Black 1992, 2004). Indeed, the Alutiiq place name translates in English as “to become numb” (Steffian and Counceller 2012), and provides an indication of the dark history and cultural importance of this site. This watershed historical event overshadows the fact that *Awa'uq* also served domestic functions over and above the relative degree of security the site offered the Alutiiq residents. Archaeological investigations led by Rick Knecht discovered at least twenty-eight house depressions, most of which were associated with a Koniag-era occupation (post-dating AD 1200; Clark 1986), as well as a large deposit of well-preserved faunal midden (Knecht et al. 2002). This paper details the analyses of faunal remains recovered in

those investigations, and sheds light on what appears to be a unique faunal assemblage from the Kodiak Archipelago.

MATERIALS AND METHODS

A 2 m x 2 m unit was excavated into well-preserved faunal midden by Knecht et al. (2002) to a maximum depth of 54 cm below the surface (Knecht n.d.). Faunal samples were primarily recovered using 13 mm (0.5”) screens (Knecht n.d.), though a few opportunistic and/or bulk samples were also collected (see below). According to Knecht et al. (2002), the midden was found to contain a variety of invertebrates (clam, mussel, chiton, urchin, and periwinkles), as well as a limited variety of mammal bones (seal and porpoise).¹ Bird bones were noted as being absent. Fish bones were not mentioned, but the midden deposit was noted to also have pieces of fire-cracked rock and gravel-tempered ceramic fragments mixed in (Knecht



Figure 1. Aerial view of Awa'uq (Refuge Rock) looking north, December 2000. Photo by Sven Haakanson, Jr. Courtesy the Alutiiq Museum.

et al. 2002). Further analysis of the faunal remains was not conducted prior to the current study. If any natural or arbitrary stratigraphic breaks were used in the field excavations, no record of that was documented. Thus, the entire assemblage is treated here as one cohesive unit, spanning an unknown period of accumulation prior to the abandonment of the village in 1784. Note that if some or all of this particular midden deposit is associated with the Koniag-age house pits, the materials could date to as early as AD 1200.

Materials were shipped from the Alutiiq Museum and Archaeological Repository in Kodiak to Etnier's lab at Western Washington University. Faunal materials were sorted into broad classes. Invertebrate remains and fish bones were only briefly examined for this study, with taxa present noted and qualitative information on abundance recorded, while all mammal and bird bones were identified to the lowest taxonomic level possible and quantified using NISP (number of identified specimens).

Comparative reference skeletons from the Burke Museum of Natural History and from Etnier's personal research collection were used to aid identifications. Male northern fur seals (*Callorhinus ursinus*) were distinguished from females based on a combination of sexually dimorphic size differences and age-specific epiphyseal fusion sequences. Age-at-death for fur seals was approximated using known-age skeletons and published growth curves (Etnier 2002). Age categories used are detailed in Table 1. Minimum number of elements (MNE, following Lyman 1994) was calculated for fur seals to test the hypothesis of differential body part representation. For this calculation, the minimum number of whole and non-overlapping portions of bone was summed separately for bones of the forelimb, the hind limb, and the axial skeleton. The observed MNEs were evaluated against expected frequencies using chi-square (Zar 1996).

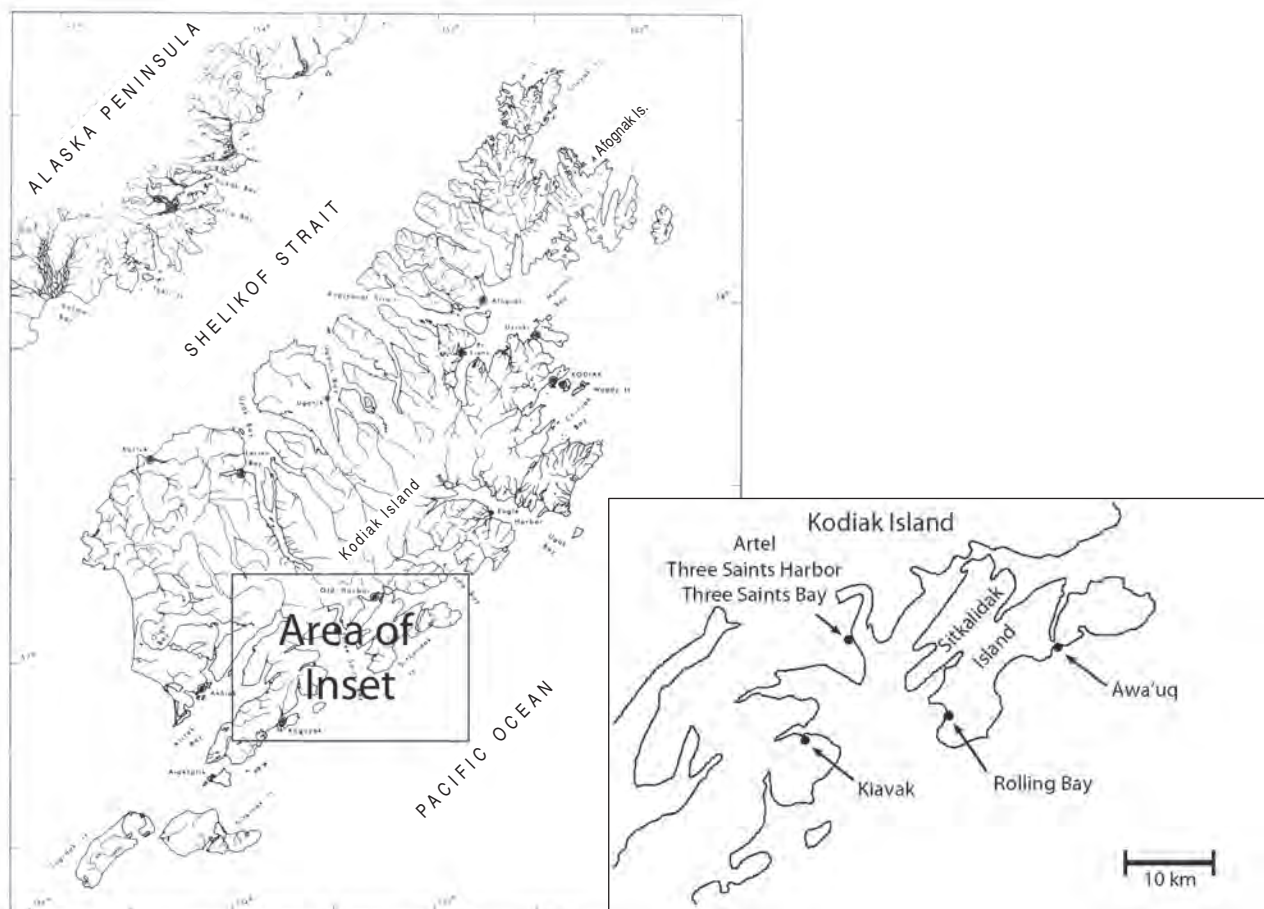


Figure 2. Kodiak Archipelago, Alaska, indicating locations of sites discussed in text. The three sites listed together with a single point on the inset map are all located within a 2 km stretch of shoreline. Inset map modified from Clark 1974.

Table 1. Age categories used to generate the harvest profile for northern fur seals.

Age Category	Characteristics and Comments
Adult	Epiphyses fully fused or annulus counts on teeth indicate adult age (3–4 years or older for females, 10–12 years or older for males)
Sub-adult	Bones at or near adult size, but lacking fused epiphyses. Note that ontogenetic maturity (fusion of epiphyses) does not necessarily correspond to reproductive maturity (see Etnier 2002).
Immature	Specimen from a young individual, but unknown whether it is old enough to be considered sub-adult (i.e., sex not known, so relative degree of development unknown)
Pup/Juvenile	Specimen obviously from a very young individual, but age unknown
Pup	A narrow window of development, from 0 to 3 or 4 months
Fetus/Newborn	Specimen approaches the size and/or development of reference skeleton of a newborn pup
Fetus	Specimen substantially smaller and/or under-developed relative to reference skeleton of a newborn pup

RESULTS

The sample of invertebrates consists of approximately 10 liters of material, most of which is bivalve and gastropod shells. A cursory examination of the invertebrates in the midden sample shows that a wide range of intertidal and subtidal species were utilized at *Awa'uq* (Table 2), including Pacific octopus (*Enteroctopus dofleini*). Although these animals were almost certainly utilized widely throughout the North Pacific in prehistoric times, I know of only one other record of octopus from an archaeological site (Atka Island, D. Hansen, pers. com., 2012).

The sample of vertebrates consists of a total NISP of 2405 (birds and mammals only). Detailed examination of the fish remains (approximately 30 liters of material) is forthcoming. However, as samples were sorted to separate the midden sample into different classes, the range of fish species was documented (Table 2). In particular, it was noted that the fish sample is dominated by cod (*Gadus macrocephalus*) and halibut (*Hippoglossus stenolepis*). Many of the bones were from large (cod and halibut) or very large (halibut) individuals.² Although cod and halibut can be caught relatively close to shore in most seasons (Mecklenburg et al. 2002), large individuals are typically only caught far offshore in deep water. Interestingly, Irish Lord (*Hemilepidotus* sp.), a sculpin inhabiting near-shore environments, appears to be the third most-abundant taxon, followed distantly by salmon (Salmonidae) and herring (*Clupea pallasii*). The herring bones were presumably collected either opportunistically or in bulk samples from the midden deposit, rather than in the 13 mm mesh screens.

The sample of birds is small (NISP = 52). However, several observations can be made about the assemblage (Table 2). First, there appears to have been a preference for waterfowl at *Awa'uq*, with mallard-sized ducks comprising 40% (22/55) of the total NISP. Second, the number of species identified ($n = 9$) is high given the small overall sample size. Finally, the sample consists of species that represent a mix of terrestrial, near-shore, and offshore environments.

In contrast to the other classes of faunal remains, the mammalian component (NISP = 2353) is extremely narrowly focused (Table 2), with only four distinct taxa represented. Furthermore, northern fur seals dominate the

assemblage, comprising 79% (967/1217) of the mammals identified to a taxonomic level lower than Class. In contrast, harbor seal (*Phoca vitulina*) comprised only 0.4% of the mammals (5/1217), consisting of a single metacarpal and four phalanges.

The age and sex composition of the fur seals is highly suggestive of the time and location they were harvested. The overall ratio of males to females cannot be determined with accuracy because large immature females cannot be distinguished from small immature males (Etnier 2002). Nevertheless, it is clear that adult females and sub-adult males make up the majority of specimens for which age and sex could be determined (Table 3). The frequency of adult male bones is low (NISP = 5).

Despite the inability to distinguish sex for the bones from young fur seals, many specimens could still be placed into broad age categories. The sample from *Awa'uq* seems to be bimodally distributed, with peaks in the fetal age class and the juvenile/immature age classes, the latter possibly representing the young born that year. Bones identified as potentially being from unweaned, rookery-age pups (i.e., aged zero to 3 or 4 months) are extremely rare, with an NISP of 2.

Because the fur seal bones are predominantly from sub-adult males and adult females, and therefore from animals of broadly similar body size, all fur seal element counts were pooled for the analysis of body-part representation. Within each body portion (forelimb, hind limb, and axial skeleton, or trunk), the observed frequencies are significantly different from expected (Table 4). Likewise, the pooled frequencies are also significantly different from the expected frequencies for forelimb, hind limb, and axial skeleton (Table 4).

DISCUSSION

Aside from the near absence of bird bones noted by Knecht et al. (2002), the initial reports of the *Awa'uq* faunas seem fairly typical of other sites in the Kodiak area. Pinnipeds [primarily harbor seal and Steller sea lion (*Eumetopias jubatus*), with lower frequencies of northern fur seal and small porpoises (harbor porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*)] are commonly recovered from sites throughout the region (Clark 1974;

Table 2. Summary faunal identification data for taxa recovered from Awa'uq.

Common Name	Scientific Name	NISP	Comment
Black katie chiton	<i>Katharina tunicata</i>	+	
Limpet, indet.	Lottiidae	+	
Periwinkle	<i>Littorina</i> sp.	+	~ One liter of sorted shells
Dogwhelk	<i>Nucella</i> sp.	+	
Neptune whelk	<i>Neptunea</i> sp.	+	
Blue mussel	<i>Mytilus</i> sp.	+	
Heart cockle	<i>Clinocardium nuttallii</i>	+	
Horse clam	<i>Tresus capax</i>	+	
Butter clam	<i>Saxidomus gigantea</i>	+	
Pacific octopus	<i>Enteroctopus dofleini</i>	3	Beak fragments, perhaps from a single individual
Barnacle, indet.	Balanidae or Semibalanidae	+	
Urchin	<i>Strongylocentrotus</i> sp.	+	Trace amounts
Herring	<i>Clupea pallasii</i>	+	Present, but in low numbers
Salmon	Salmonidae	+	Present, but in low numbers
Cod	<i>Gadus macrocephalus</i>	+	Abundant; many large individuals present
Irish Lord	<i>Hemilepidotus</i> sp.	+	Common
Halibut	<i>Hippoglossus stenolepis</i>	+	Abundant; many large and extremely large individuals present
Duck, indet.	Anatidae, indet.	5	Mallard-sized
Dabbling duck	<i>Anas</i> sp.	17	Mallard-sized
Auks, puffins, and murres	Alcidae	1	
Auks, puffins, and murres	cf. Alcidae	3	
Murre	<i>Uria</i> sp.	2	
Gull	<i>Larus</i> sp.	2	
Ptarmigan	<i>Lagopus</i> sp.	2	
Loon (Pacific or red-throated)	<i>Gavia stellata/pacifica</i>	1	
Albatross	<i>Phoebastria</i> sp.	5	
Northern fulmar	<i>Fulmarus glacialis</i>	1	
Shearwater	<i>Puffinus</i> sp.	4	
Bald eagle	<i>Haliaeetus leucocephalus</i>	1	
Bird, indet.	Aves	8	
Seal, fur seal, or sea lion	Pinnipedia	112	Probably all or mostly fur seal
Fur seal or sea lion	Otariidae	30	Probably all fur seal
Northern fur seal	<i>Callorhinus ursinus</i>	937	See Table 3 for age/sex composition
Northern fur seal	cf. <i>Callorhinus ursinus</i>	30	
Harbor seal	<i>Phoca vitulina</i>	5	Four phalanges and one metacarpal
Dolphin, indet.	Delphinidae	78	
Whale, indet.	Cetacea	25	
Mammal, indet.	Mammalia	1136	Probably a mix of Delphinidae and fur seal
TOTAL*		2405	

*Total does not include the octopus beaks

Table 3. Harvest profile for fur seals from Awa'uq, compared with the aggregate harvest profile for Three Saints Bay, Kia-vak, and Rolling Bay (from Etnier 2002). Absolute ages from Etnier (2002) have been converted to match the categorical ages used here.

		<i>Awa'uq</i>		Rolling Bay Sites	
		NISP	Percent	NISP	Percent
Sex determined					
	Female, adult	93	42.7	37	50.7
	Female, sub-adult	33	15.1	2	2.7
	Male, adult	5	2.3	2	2.7
	Male, sub-adult	87	39.9	32	43.9
	Totals	218	100	73	100
Sex indeterminate					
	Fetus	2	1.3	1	3.2
	Fetus/Newborn	37	23.1	0	0.0
	Pup (?)	2	1.3	3	9.7
	Pup/Juvenile	33	20.6	9	29.0
	Immature	80	50.0	18	58.1
	Sub-Adult	6	3.7	0	0.0
	Totals	160	100	31	100

Kopperl 2003; Schaaf n.d.; Yesner 1989), as are a wide variety of intertidal and subtidal invertebrates (Foster 2004; Odell n.d.).

In terms of the birds, fish, and invertebrates, the additional analyses presented here, while still incomplete, generally align the *Awa'uq* faunal assemblage with those from other sites in the region. However, the narrow focus on fur seals at *Awa'uq* appears to be unique among archaeological sites in the Kodiak Archipelago. Does this mark an early attempt by the Alutii to play an active role in the Russian fur trade? Were they stock-piling food in anticipation of a potential siege? Or does the high frequency of fur seals simply reflect a narrowly focused seasonal hunting strategy that capitalized on the proximity of the site to the fur seals' migration route?

Don Clark (1974, 1986) has noted an apparent increase in fur seal use through time based on analysis of faunal samples from elsewhere in the southern Kodiak Archipelago (Fig. 1). Based on the ratio of fur seal NISP to harbor seal NISP (Table 5), he sees evidence for increased reliance on fur seals, starting at low levels about 1000 years ago and extending forward into the proto-historic period (early 18th century) in what he characterized as a trend (Clark 1986:41). If Clark's data really represent a

trend, the faunal assemblage from *Awa'uq*, occupied until August 1784, seems to have reached its natural end-point, with the near total absence of harbor seals (Table 5).

Even so, the age and sex composition of the *Awa'uq* assemblage is broadly similar to that of the assemblages noted by Clark (1986) and further analyzed by Etnier (2002; Table 3). The main difference between these assemblages is seen in the higher relative abundance of bones in the "fetus/newborn" category recovered from *Awa'uq*. The presence of fetuses, and the lack of pups in these harvest profiles suggest that fur seals were not hunted from a nearby, previously unidentified rookery.³ Rather, it indicates that juveniles and pregnant adult females were hunted in the open ocean in late spring or early summer as they migrated past Kodiak on their way to the breeding grounds in the Pribilof Islands, or perhaps somewhere in the Aleutian Islands (Crockford 2012; Newsome et al. 2007). Fur seals may also have been hunted on their return to the south during the fall migrations. Because of the coarse nature of the age estimates, the two specimens provisionally assigned to the "newborn pup" category should not be taken as evidence of a local, previously undocumented fur seal breeding colony (Newsome et al. 2007).

Table 4. Minimum number of elements (after Lyman 1994) from various portions of the body for fur seals. “Base” is the number of each element found in a complete carcass. “Observed” is the frequency identified from the Awa’uq assemblage. “Expected” is the frequency expected based on the observed sub-total for that range of elements. Chi-square values: forelimb $\chi^2 = 42$; hind limb $\chi^2 = 67$; axial skeleton $\chi^2 = 20$; $p > 0.001$; $df = 5$. Pooled frequencies for forelimb, hind limb and axial skeleton: $\chi^2 = 9.3$; $p = 0.009$; $df = 2$.

	Base	Observed	Expected
Forelimb			
Scapula	2	5	5.2
Humerus	2	12	5.2
Radius	2	13	5.2
Ulna	2	9	5.2
Carpals	12	8	31.2
Metacarpals	10	31	26
Subtotal	30	78	78
Hind Limb			
Pelvis	2	12	6
Femur	2	21	6
Tibia	2	14	6
Fibula	2	7	6
Tarsals	14	24	42
Metatarsals	10	18	30
Subtotal	32	96	96
Axial Skeleton			
Teeth (canines only)	4	7	15.7
Cranium	1	11	3.9
Mandible	2	6	7.8
Cervical Vertebrae	7	31	27.4
Thoracic Vertebrae	16	58	62.6
Lumbar Vertebrae	5	24	19.6
Subtotal	35	137	137
Combined Data			
Forelimb	30	96	96.2
Hind Limb	32	78	102.6
Axial Skeleton	35	137	112.2
Subtotal	97	311	311

As Clark (1986) points out, the beginnings of the Kodiak fur seal harvests were not related to the commercial fur trade because the earliest fur seal bones substantially predate any Russian presence in Kodiak. However, by the middle of the 18th century, Russian fur traders were well known to the Alutiit, and had been for many decades (Black 1992, 2004; Luehrmann 2008). In fact, low frequencies of Euro-American trade goods were recovered from Awa’uq (Knecht et al. 2002), indicating at least some direct or indirect trade. Several lines of evidence, however, suggest that the Alutiit residents at Awa’uq were not stockpiling furs in anticipation of trade with the Russians. First, the dating of the midden deposit is completely unresolved. The accumulation of bones could span decades or millennia. Second, no sea otter (*Enhydra lutris*) bones were recovered from the midden, though sea otters would have been more highly sought for their furs than fur seals, and would still have been at pre-commercial population levels. Third, interactions between Russian traders and the Alutiit prior to the siege at Awa’uq had been anything but peaceful (Black 1992, 2004; Crowell 1997).

Given the time of year the siege took place (August), fur seals were also clearly not stock-piled in anticipation of a siege. The migrating fur seals would have been harvested primarily in late May or early June, at which point Grigorii Shelikhov and his men would have been in the Aleutian Islands, en route to Unalaska Island (Crowell 1997).

All of these points suggest that the faunal assemblage from Awa’uq represents the remains of a narrowly focused subsistence strategy. But even if Awa’uq were a uniquely situated seasonal hunting camp focused on pelagic sea mammals, the near-total absence of harbor seals still requires explanation. The low frequency of harbor seal bones could have arisen through one of three scenarios:

1. harbor seals were not present in the area in substantial numbers;
2. harbor seals were present as they are today, but not harvested in any appreciable numbers;
3. harbor seals were present as they are today, and harvested in proportion to their abundance, but not deposited in and/or recovered from the midden that was excavated by Knecht et al. (2002).

Scenario 1 does not seem particularly likely, given that nearby sites that immediately post-date the abandonment of Awa’uq, the Artel site (Clark 1986) and Three Saints Harbor (Crowell 1997), both contain harbor seal bones (172/282 and 7/50, respectively, of total mammal NISP; see also Table 5). Nor does Scenario 2 seem likely. The

Table 5. NISPs and the ratio of fur seals to harbor seals from sites discussed in text. Data for Three Saints Bay, Kiavak, Rolling Bay, and the Artel site from Clark (1986). “NISP Mammals” includes only those specimens identified to a taxonomic category lower than class.

Site	Date AD	NISP fur seal	NISP harbor seal	NISP mammals	Ratio
Three Saints Bay	1–1000	20	167	371	1:8
Kiavak	1700s	50	92	243	1:2
Rolling Bay	1700s	184	58	316	3:1
Artel	1780s	98	172	282	1:2
<i>Awa’uq</i>	1200 (?) to 1780s	967	5	1217	193:1

limited data available for the invertebrate and fish remains indicate that at least some foraging activity was occurring in the near-shore waters. Absent any culturally mediated avoidance of harbor seals, basic foraging theory tenets indicate they would always be taken upon encounter (cf. Broughton 1994).

According to Scenario 3, for whatever reason, the bones of harvested harbor seals were not deposited and/or recovered by Knecht et al.’s excavations. It is worth noting that *Awa’uq* is bounded by cliffs, with extremely limited access to the top of the sea stack (Fig. 2). Thus, large-bodied animals such as harbor seals (adults can weigh up to 170 kg, compared to an adult female fur seal that weighs ~40 kg) may have been butchered on the beach, with only the meat transported up the cliffs to the village.

I have demonstrated that fur seal skeletal element frequencies do not match the expected frequencies of a complete skeleton. However, the specific ways in which they depart from expected do not clearly match what would be predicted from transport decisions. Specifically, the bones of the forelimb are all over-represented except for the bones of the wrist (Table 4). If front flippers were being systematically removed for differential treatment, either as specialty food items or for discard on the beach, then carpals and metacarpals should be affected similarly. The situation is less clear for bones of the axial skeleton, with thoracic vertebrae and canine teeth being slightly under-represented, and bones of the cranium slightly over-represented. The only body segment with frequencies that may result from transport decisions is the hind limb, where tarsals and metatarsals are both under-represented in the assemblage. On balance, the MNE data indicate that transport decisions did not significantly affect fur seal element frequencies—a finding not that is too surprising for carcasses that would have weighed on the order of 40 kg and could have been transported in their entirety. Another

possibility is that front and rear flipper bones were not recovered in the process of screening the midden deposits. However, if the element representation of the limbs were a function of recovery bias associated with the use of 13 mm screens, it is unclear why metatarsals would be affected while metacarpals were not.

The best way to resolve the issue would be more detailed excavations at *Awa’uq*. Not only would this help determine the antiquity of the village, but it could also shift the emphasis of the site’s history further away from the dark final days of occupation and shed light on the origins and development of such a heavy reliance on fur seals.

CONCLUSION

The midden samples from *Awa’uq* indicate that the Alutiiq residents harvested a wide range of intertidal, subtidal, near-shore, and pelagic resources. However, their main focus was a highly specialized harvest of migrating fur seals in late spring and perhaps also in the fall. Harbor seals appear to have not been harvested in appreciable numbers, despite the fact that other near-shore resources (invertebrates, fish, birds) were harvested.

Awa’uq is a somber place with a dark history. But the history of the people who lived there is much more complicated than suggested by a single, violent event. It is not uncommon for archaeological sites to exhibit characteristics of “special-use” sites. What makes *Awa’uq* so unique is the degree of specialization that appears to have taken place here. Despite the painful history of this site, recovery of additional midden samples could provide valuable insights into the origins of and the final days of a subsistence economy unique in the Kodiak Archipelago.

ACKNOWLEDGEMENTS

This research was funded through a Cooperative Agreement between Western Washington University and Lake Clark National Park and Preserve (H8W07060001), through the Pacific Northwest Cooperative Ecosystems Studies Unit. Thanks to the Kodiak Area Native Association for granting permission to analyze the materials from this important site. Thanks also to the Alutiiq Museum and Archaeological Repository, Kodiak, and the Burke Museum of Natural History and Culture, Seattle, for their cooperation in providing access to the *Awa'uq* collections. Carlile Transportation Systems graciously covered shipping costs between Kodiak and Bellingham. The manuscript has benefitted greatly from comments by Jeanne Schaaf, Don Clark, and Aron Crowell.

NOTES

1. Scientific names were not used by Knecht et al. (2002), leading to some confusion as to what taxa were present in the assemblage.
2. The largest cod bones were comparable in size to those from a one-meter-long individual in Etnier's reference collection, while the halibut bones were as large as or larger than those from a two-meter-long individual in Etnier's reference collection. Maximum reported sizes for these species are 1.2 m and 2.7 m, respectively (Froese and Pauly 2012).
3. Note that fur seals do not typically "haul out," or rest, in nonbreeding aggregations except immediately adjacent to breeding colonies (Gentry 1998).

REFERENCES

- Black, Lydia T.
1992 The Russian Conquest of Kodiak. *Anthropological Papers of the University of Alaska* 24:165–182.
2004 *Russians in Alaska, 1732–1867*. University of Alaska Press, Fairbanks.
- Broughton, Jack M.
1994 Declines in Mammalian Foraging Efficiency during the Late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology* 13:371–401.
- Clark, Donald W.
1974 *Koniag Prehistory: Archaeological Investigations at Late Prehistoric Sites on Kodiak Island, Alaska*.

- Tübinger Monographien zur Urgeschichte. Verlag W. Kolhammer, Stuttgart.
- 1986 Archaeological and Historic Evidence for an 18th-Century "Blip" in the Distribution of the Northern Fur Seal at Kodiak Island, Alaska. *Arctic* 39:39–42.
- Crockford, Susan J.
2012 Archaeozoology of Adak Island: 6000 Years of Subsistence History in the Central Aleutians. In *The People Before: The Geology, Paleoecology and Archaeology of Adak Island, Alaska*, edited by D. West, V. Hatfield, E. Wilmerding, C. Lefèvre, and L. Gualtieri. BAR International Series 2322. Archaeopress, Oxford.
- Crowell, Aron L.
1997 *Archaeology and the Capitalist World System: A Study from Russian America*. Plenum Press, New York.
- Etnier, Michael A.
2002 The Effects of Human Hunting on Northern Fur Seal (*Callorhinus ursinus*) Migration and Breeding Distributions in the Late Holocene. Unpublished Ph.D. dissertation. Department of Anthropology, University of Washington, Seattle.
- Froese, Rainer, and Daniel Pauly, editors
2012 Fishbase. World Wide Web electronic publication. www.fishbase.org, version 10/2012.
- Foster, Nora
2004 Shellfish Remains from the Mink Island Site, Katmai National Park and Preserve, Alaska. Unpublished manuscript on file, National Park Service, Anchorage.
- Gentry, Roger L.
1998 *Behavior and Ecology of the Northern Fur Seal*. Princeton University Press, Princeton, NJ.
- Knecht, Richard A.
n.d. *Awa'uq* 1992 field season. Unpublished field notes on file, Alutiiq Museum and Archaeological Repository, Kodiak, AK.
- Knecht, Richard A., Sven Haakanson, and Shawn Dickson
2002 *Awa'uq*: Discovery and Excavation of an 18th Century Alutiiq Refuge Rock in the Kodiak Archipelago. In *To the Aleutians and Beyond*, edited by B. Frohlich, and R. Gilberg. Publications of the National Museum Ethnographical Series, vol. 20, pp. 177–191. Department of Ethnography, National Museum of Denmark, Copenhagen.

- Kopperl, Robert E.
2003 Cultural Complexity and Resource Intensification on Kodiak Island, Alaska. Unpublished Ph.D. dissertation. Department of Anthropology, University of Washington, Seattle.
- Luehrmann, Sonja
2008 *Alutiiq Villages under Russian and U.S. Rule*. University of Alaska Press, Fairbanks.
- Lyman, R. Lee
1994 Relative Abundances of Skeletal Specimens and Taphonomic Analysis of Vertebrate Remains. *Palaos* 9:288–298.
- Mecklenburg, Catherine W., T. Anthony Mecklenburg, and Lyman K. Thorsteinson
2002 *Fishes of Alaska*. American Fisheries Society, Bethesda, MD.
- Newsome, Seth D., Michael A. Etnier, Diane Gifford-Gonzalez, Donald L. Phillips, Marcel van Tuinen, Elizabeth A. Hadly, Daniel P. Costa, Douglas J. Kennett, Tom P. Guilderson, and Paul L. Koch
2007 The Shifting Baseline of Northern Fur Seal Ecology in the Northeast Pacific Ocean. *Proceedings of the National Academy of Sciences* 104(23):9709–9714.
- Odell, Molly
n.d. Analysis of Shellfish Remains from Miktsqaq Angayuk and Settlement Point. Unpublished manuscript on file, Department of Anthropology, University of Washington, Seattle.
- Schaaf, Jeanne M.
n.d. Analysis of Vertebrate Remains from the Mink Island site, Katmai National Park and Preserve, Alaska. Unpublished data on file, National Park Service, Anchorage.
- Steffian, Amy F., and April L.G. Counceller
2012 *The Alutiiq Word of the Week Fifteen Year Compilation*. Alutiiq Museum & Archaeological Repository, Kodiak, AK.
- Yesner, David R.
1989 Osteological Remains from Larsen Bay, Kodiak Island, Alaska. *Arctic Anthropology* 26(2):96–106.
- Zar, Jerrold H.
1996 *Biostatistical Analysis*, 3rd ed. Prentice Hall, Upper Saddle River, NJ.

MIDDLE HOLOCENE HUMANS IN THE YUKON-CHARLEY RIVERS NATIONAL PRESERVE, ALASKA

Ian Buvit

Department of Anthropology and Museum Studies, Central Washington University; 400 E. University Way, Ellensburg, WA 98926;
buviti@cwu.edu

Jeff Rasic

National Park Service, Yukon-Charley Rivers National Preserve, 4175 Geist Road, Fairbanks, AK 99769; jeff_rasic@nps.gov

ABSTRACT

In 2008, Central Washington University archaeologists in collaboration with the National Park Service conducted limited subsurface testing at the Slaven's Roadhouse site (CHR-00030) at the confluence of Coal Creek and the Yukon River about 100 km upstream from the town of Circle, Alaska. Slaven's is the location of a historic building, but of interest are deeply stratified alluvial deposits likely spanning the entire Holocene and latest Pleistocene. We excavated three 1 m x 2 m units to discover a buried cultural layer around 50 cm below the surface associated with a layer of timbers. The timbers date to ~2500 BC and may comprise a Northern Archaic cultural feature. Although the cultural assemblage is small, dated finds from this region are rare and the excellent stratigraphic context and chronological control make it worth reporting.

INTRODUCTION

Detection of archaeological material is often difficult in the Alaska boreal forest, especially when the objects of interest are small, flaked-stone artifacts. Many areas are characterized by thick, continuous ground cover and tussocky terrain that severely limit travel. Though not ideal, one way to overcome this is to survey along exposed cutbanks of active streams when access to higher positions is limited due to loose sediments or steep slopes. Another strategy is to implement exploratory subsurface testing on landforms, such as alluvial terraces, at the confluences of streams thought to have been used by humans in the past.

Few stratified sites are known for Yukon-Charley Rivers National Preserve, even though the region likely has a very long history of human use and deep, stratified deposits. In 2008, we excavated three 1 m x 2 m test units using an exploratory strategy at the Frank Slaven Roadhouse site (CHR-00030) and discovered a buried

flaked-stone projectile point associated with a burnt timber feature of possible cultural origin.

The Frank Slaven Roadhouse site is a historic log and wood-frame building and associated outbuildings constructed about 1930; it is maintained and administered today by the National Park Service within Yukon-Charley Rivers National Preserve. The site is situated on a high bench at the confluence of Coal Creek on the left bank of the Yukon River (65°21'02"N, 143°07'12"W) (Figs. 1 and 2). The preserve is part of the Yukon-Tanana Uplands and characterized by rounded, even-topped ridges and low hills; peaks of the Ogilvie Mountains at the headwaters of the Charley River reach over 1,500 m (Brabets et al. 2000).

The Yukon River and its larger tributaries contain expansive areas with deep, stratified alluvial deposits that may contain buried cultural material. Thorson (1982) identified at least four Yukon River terraces, which he labeled Y4 to Y1 from oldest to youngest with age estimates

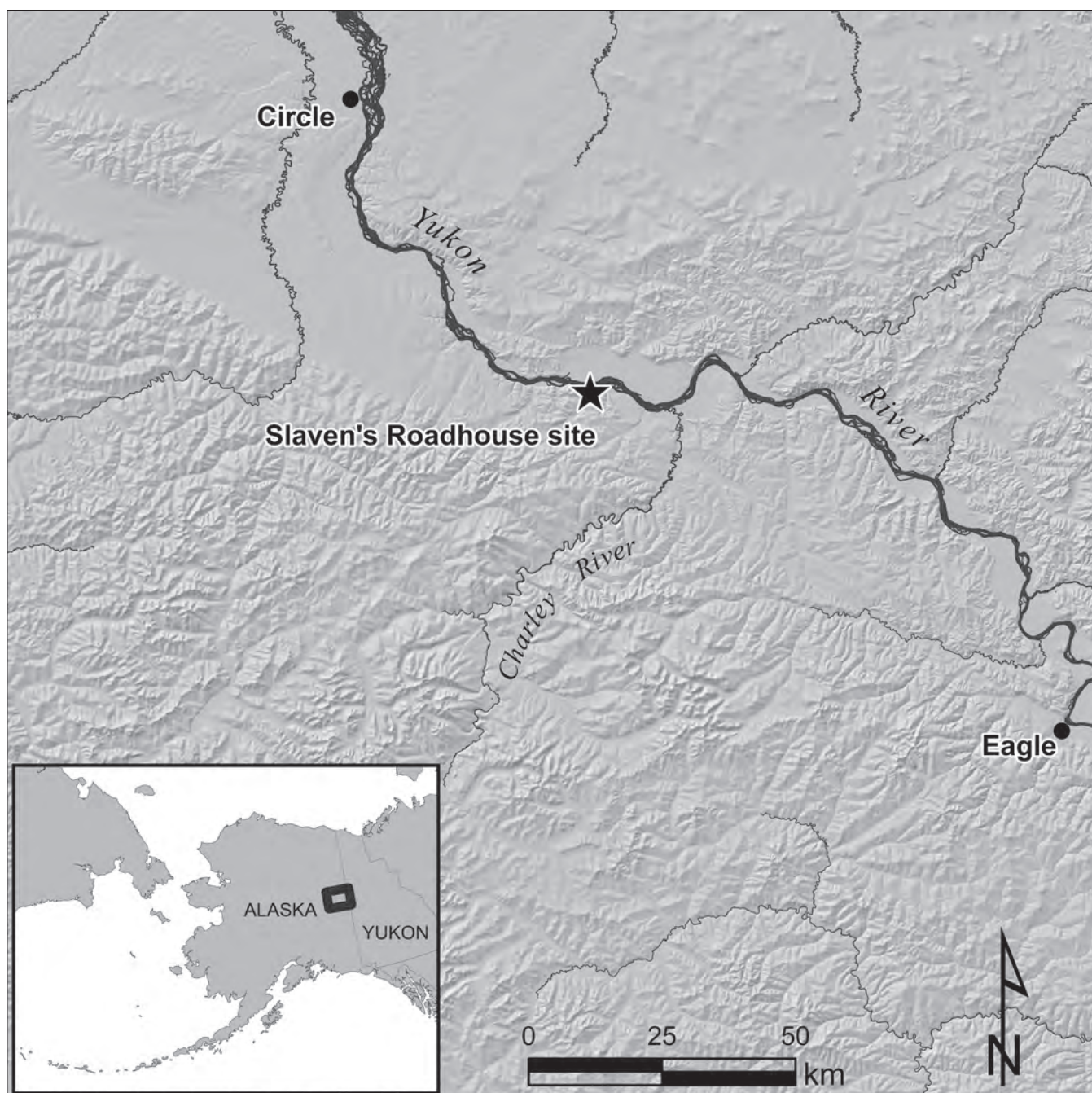


Figure 1. Map showing the location of Slaven's Roadhouse (CHR-00030) between Circle and Eagle in east-central Alaska.

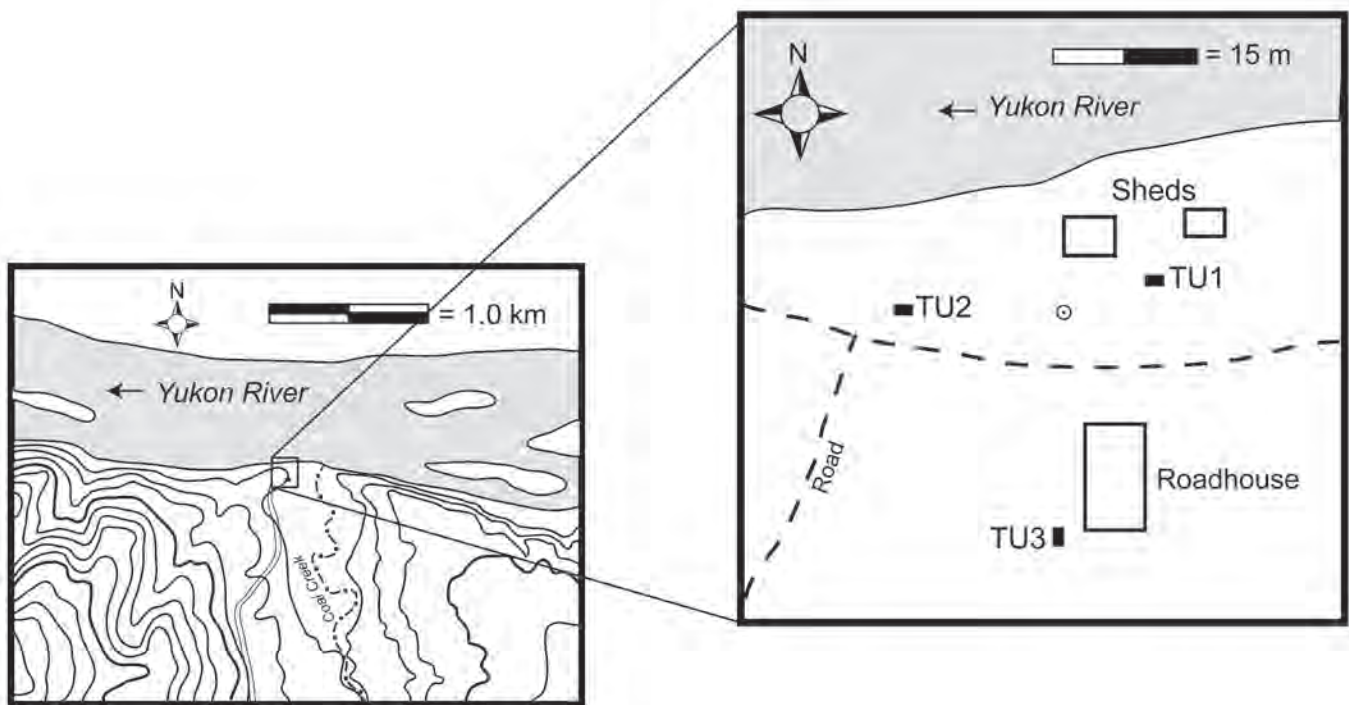


Figure 2. Map of Slaven's Roadhouse area showing the locations of the excavation units in relation to the Yukon River and historic structures.

from the middle Pleistocene for the highest surfaces to the middle Holocene for some of the lower formations. He also reported four terraces of various ages and heights associated with major tributaries of the Yukon, labeled T4 to T1 from oldest to youngest. Slaven's Roadhouse is likely located on either Y2 or T2, which Thorson (1982) contends date between around 50,000 and 13,000 years ago. In addition, recent geological work has begun to identify and date specific landforms (i.e., river terraces) (Buvit and Rasic 2010), tephra layers (Froese et al. 2005; Mason and Beget n.d.), and paleosols that provide independent dating controls for archaeological materials.

Archaeological potential in the upper Yukon River region is thought to be high for a variety of reasons. Adjacent areas of central Alaska contain sites approaching 14,000 ^{14}C BP that are among the earliest in North America (Hoffecker and Elias 2003; Holmes 2001, 2012). As such, the massive and productive Yukon River is likely to have been a focus of human subsistence and an important route of travel considering the area has not been extensively glaciated since the early-middle Pleistocene-age Charley River Glaciation (Weber 1986), constrained to 560,000 to 780,000 years ago (Froese et al. 2003). Important sites dated to the middle Holocene and assigned to the Northern Archaic Tradition, such as Charley River 1 and

Red Ochre, are located nearby (Esdale 2008). The Han (Crow and Obley 1981; Mishler and Simeone 2004) and Gwich'in (Arndt 1996:199–202; Slobodin 1981) inhabited the region in the historic period; archaeological manifestations of Athapaskan villages, hunting and trapping locations, and camps are present.

The upper Yukon River region is therefore likely to have a long history of human occupation, and it exhibits the proper geological context for the preservation of archaeological sites; however, there are surprisingly few sites in the area that have been identified or subject to even small-scale subsurface testing. Among these is the Twelve Mile Bluff (CHR-00007) locale (West et al. 1965). Located on the top of a prominence above the Yukon River downstream from Circle, the site was subject to approximately 40 m² of test excavations in 1963 and 1964. The site is undated, but was assigned to the mid-Holocene Northern Archaic period based on the presence of side-notched bifacial projectile points and notched pebble tools. Some 35 formed or utilized tools and approximately 2000 pieces of flaking debris were reported.

Further upstream in Canada stratified sites include Moosehide (LaVk-2) and Forty Mile or Ch'ëdä Dëk (LeVn-2). The Moosehide site, located two miles below Dawson in the Yukon Territory, contains three components, one

dating to the early Holocene (c. 6950 cal BC), one to the middle Holocene with microblades and side-notched projectile points, and one to the historic period (AD 1730) (Jeff Hunston, written comm.). Excavations at the Forty Mile site, located near the Alaska-Canada border at the mouth of the Fortymile River, revealed historic, protohistoric and prehistoric components dating to as old as 2300 years ago (Hammer and Thomas 2006).

Few known prehistoric sites, fewer excavated assemblages, and even fewer collections from stratified contexts exist. With this in mind we aim to put on record our admittedly preliminary results from test excavations at Slaven's Roadhouse. A factor contributing to the significance of Slaven's and other sites in Yukon-Charley is the geological contexts in which they are likely to be found. Deposits along this stretch of the river are primarily low-energy, fine-grained overbank alluvium and loess or eolian sand (Froese et al. 2005; Livingston et al. 2008), charac-

teristics shown to be highly conducive to site preservation and dating (Bettis and Mandel 2002; Guccione 2008; Guccione et al. 1998).

RESULTS

Our focus will be limited to Test Unit 3 where we discovered the buried projectile point and timbers. Stratigraphically, the Test Unit 3 profile is divided into five layers (Figure 3). Unit I is very dark grayish brown (10YR3/2) exhibiting interlaminated bedding and loamy texture. A wood sample produced a radiocarbon date of 2515 cal BC (3970 ± 40 ¹⁴C BP) (Beta-258420) (Fig. 3, Table 1). Continuing upward through the profile, Unit II is a massively bedded, dark olive brown (2.5Y3/3) clay loam layer in which the flaked-stone projectile point was discovered. At the top of Unit II is a layer of timber directly overlying the artifact. A piece of wood from the base of the timbers was radio-

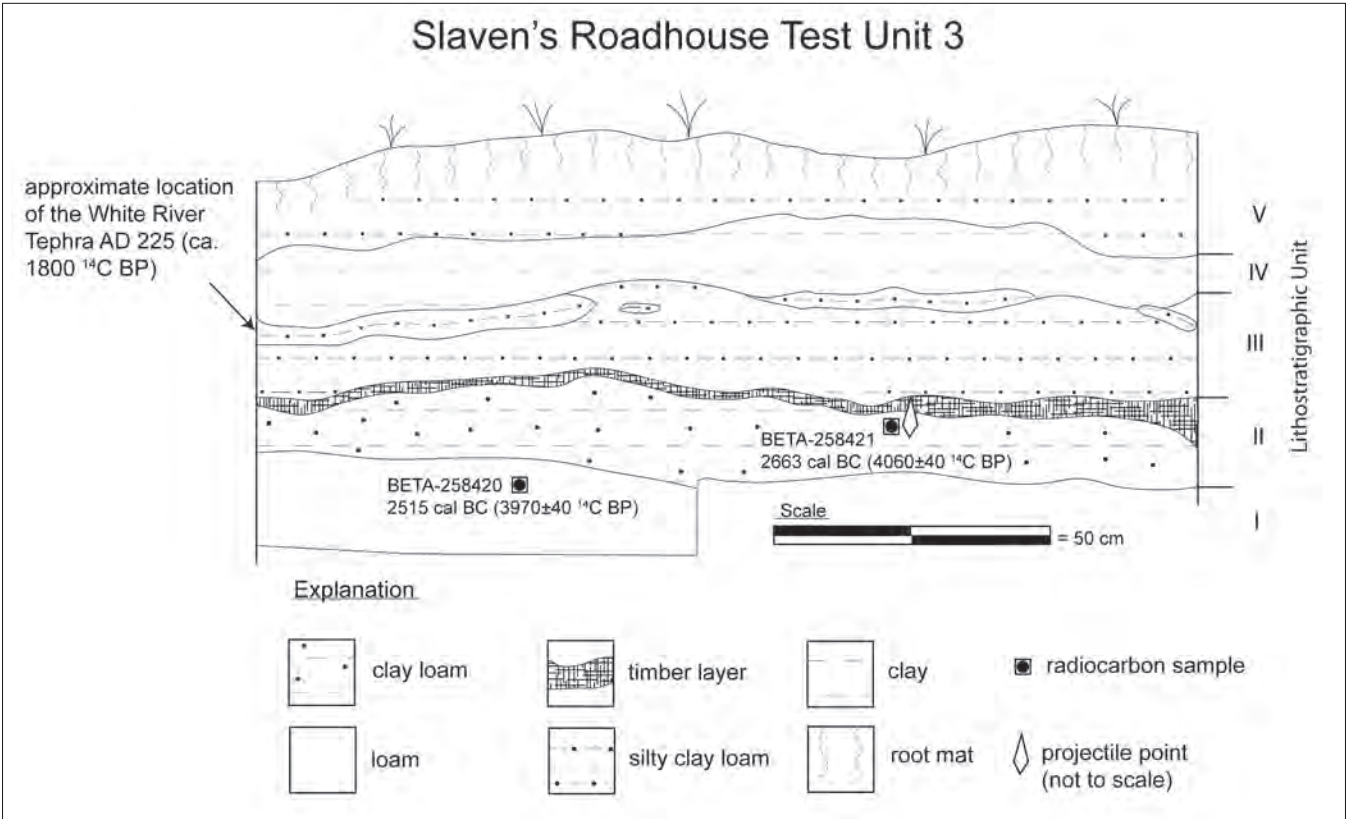


Figure 3. Stratigraphic profile of Test Unit 3.

Table 1. Radiocarbon AMS dates from Test Unit 3 at Slaven's Roadhouse. Calibration follows Reimer et al. (2004).

sample #	¹⁴ C age yr BP	δ ¹³ C (‰)	cal age range BC (1σ)	material
Beta-258420	3970 ± 40	-25.6	2570–2460	wood
Beta-258421	4060 ± 40	-23.9	2830–2490	wood

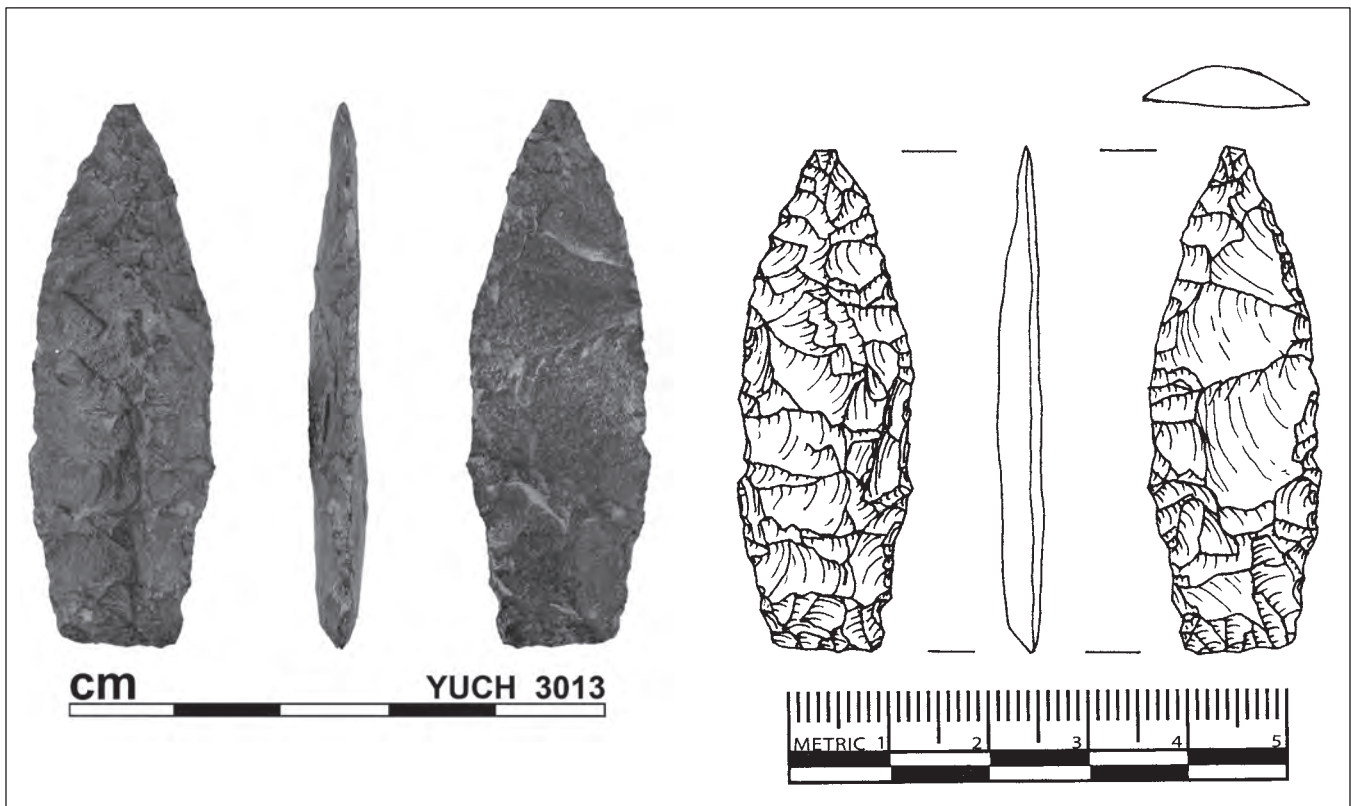


Figure 4. Projectile point from Slaven's Roadhouse. Dimensions: 50.3 mm long; 4.0 mm maximum thickness; 16.4 mm maximum width; 5.04 g. Line drawing by Sarah Moore.

carbon dated to 2663 cal BC (4060 ± 40 ^{14}C BP) (Beta-258421). Unit III, a bed of silty clay loam, exhibits massive bedding and dark olive brown color (2.5Y3/3). In addition, several organic-rich darker lenses were discovered at the top of Unit III. Elsewhere in the excavation unit, remnants of a tephra were identified. Although no samples were collected, it is likely the White River Ash based on its stratigraphic position, thickness, color and texture compared to studies of known exposures widely distributed across the region (Clague et al. 1995; Lerbekmo 2008; Lerbekmo and Campbell 1969; Robinson 2001). Unit IV is a very dark gray (2.5Y3/1) clay bed. Finally, Unit V is a massively bedded, very dark grayish brown (10YR3/2) silty clay loam layer on which the modern root mat is developing.

The laminated bedding in Unit I at the base of the exposed profile indicates a likely fluvial origin of these sediments. We cannot say for certain whether the upper layers are also alluvia, but given the general fining-upward character of the set, they could reflect low-energy overbank deposits from the Yukon River or Coal Creek. Otherwise, units II–V could be eolian in origin. Regardless, the projectile point and timbers are associated with what is, and

was at the time of occupation, a high, stable landform. Statistically, the radiocarbon ages from the profile are equivalent (Table 1), indicating rapid deposition of the sediments between the dated samples (i.e., Unit II).

The projectile point is a lanceolate form with a straight base made of a dark gray, coarse-grained chert (Fig. 4). It is complete and relatively small, measuring 50.3 mm long. The lateral cross-section is plano-convex in shape, which reflects its production from a flat flake blank that was minimally worked on its ventral surface. Flaking on the opposite face is non-patterned, and the size and spacing of flake scars indicate that the artifact was entirely shaped through pressure flaking. There is no evidence of purposeful haft modifications; the lateral margins of the projectile point are not ground or polished. A subtle indentation at the proximal end, however, gives the impression of a stemmed basal shape, but this is more apparent than real, and results largely from removal of a single flake on one face rather than a purposeful effort to produce a stemmed hafting element. The opposite margin lacks any sign of a stemmed shape. The biface is interpreted to be a finished tool rather than a preform given its refined shape and carefully flaked margins; its function is interpreted to

be a projectile tip due to its pointed, symmetrical shape, although a hafted knife or multipurpose knife-projectile function is also possible. No diagnostic use traces were observed under low magnification. Aside from the lithic projectile point, several nails, glass fragments, plastic and other pieces of modern refuse were recovered from the root mat. It is possible that the timbers overlying the biface at the top of Unit II represent a cultural feature. Without continued excavations, though, it is difficult to confirm.

DISCUSSION AND CONCLUSIONS

The form and technology of the Slaven's biface have not been clearly recognized in the region for this time period. While side-notched projectile points are emblematic of this period and are characteristic of assemblages assigned to the Northern Archaic Tradition, their technological and morphological variation, and the degree to which there is chronological patterning in this variation, is still only provisionally understood (Esdale 2008; Hare et al. 2008). Much less is known about technologies that fall in the lanceolate and leaf-shaped category like the Slaven's biface. Among the few examples reported in the literature is a specimen illustrated by Workman (1978:498) from the Chimi site in the southern Yukon. It is similar to the Slaven's biface in size and shape, and derives from a similar method of manufacture. Both artifacts were produced with a frugal approach to biface manufacture, which involved minimal flaking of a flake blank that left substantial unworked remnants of the original blank. The Chimi artifact unfortunately derives from an undated surface context. Of note, however, is that it was highlighted as unique among the extensive collections from Chimi, which included eight classes of bifacial projectile points from the middle Holocene-age Taye Lake component. Likewise, Hare et al. (2008:331) recognize a "Constricting Base Point" class among their database of more than 500 hafted bifaces from the Yukon Territory; the Slaven's specimen falls most clearly within this class. It is, however, described as a provisional artifact class limited to only five undated pieces. None of the directly dated stone projectile tips from ice-patch finds in central Alaska, Yukon, or Northwest Territories compare well with the Slaven's biface (Dixon et al. 2005; Hare et al. 2008, 2012). This is perhaps unsurprising given the riverine setting of the Slaven's site compared to the montane context of the ice-patch finds and the contrasting activities expected in such different ecological settings.

While the preliminary results presented here are far from a full description of the technological complex of the prehistoric inhabitants of the Slaven's Roadhouse site, a few useful facts can be added to the valuable database of sites and artifacts from well-controlled stratigraphic contexts. One contribution is good chronological control for a projectile point or hafted biface of the sort that has potential as a chronological marker. This work demonstrates a need to conduct intensive testing in order to locate sites with low artifact densities. Such sites, like Slaven's Roadhouse, may provide good stratigraphic contexts and clear chronological control.

The presence at Slaven's Roadhouse of a prehistoric artifact in a buried, dateable context demonstrates that the potential exists for more significant archaeological discoveries along this stretch of the Yukon River. Continued work that defines the terrace systems of the Yukon and its major tributaries, including where Slaven's is located, will provide an important baseline for future archaeological studies. This strategy, using historic geomorphology, was applied to Pleistocene-age landforms in Central Alaska where Hoffecker (1988) created a predictive model based on the estimated ages of glacial-fluvial and alluvial formations. A similar study in Yukon-Charley Rivers National Preserve, where sites can often only be detected through exploratory subsurface testing, would be highly informative.

Currently, a relatively large number of late Pleistocene through Holocene sites are known from central Alaska, generally found along highway corridors. But despite intensive and extensive surveys of exposed cutbanks along this stretch of the Yukon River, very few sites have been discovered; nearly all have dated to the late Holocene (following the White River Ash fall). Why the difference? We suggest it results from the deep stratigraphic exposures in central Alaska (e.g., at roadcuts), the accessibility of these areas, and the region's long history of research. The paucity of early sites along the upper Yukon River, in contrast, is a manifestation of sampling rather than an indicator that people did not use this area in the past.

ACKNOWLEDGMENTS

We wish to thank Joe Keeney, Neal Endacott and Laura Dice for their time excavating. We also wish to thank National Park Service personnel at Eagle, Alaska, who helped with project logistics.

REFERENCES

- Arndt, Katherine L.
1996 *Dynamics of the Fur Trade on the Middle Yukon River, Alaska, 1839 to 1868*. Ph.D. dissertation, Department of Anthropology, University of Alaska Fairbanks.
- Bettis III, Arthur E., and Rolfe D. Mandel
2002 The Effects of Temporal and Spatial Patterns of Holocene Erosion and Alluviation on the Archaeological Record of the Central and Eastern Great Plains, U.S.A. *Geoarchaeology* 17(2):141–154.
- Buvit, Ian, and Jeff Rasic
2010 Recent Survey and Subsurface Testing in the Yukon-Charley National Preserve, AK. Paper presented at the 63rd Annual Meeting of the Northwest Anthropological Conference, Ellensburg, WA.
- Brabets, Timothy, Bronwen Wang, and Robert H. Meade
2000 *Environmental and Hydrologic Overview of the Yukon River Basin, Alaska and Canada*. U.S. Geological Survey Water-Resources Investigations Report 99-4204. Anchorage.
- Clague, J.J., S.G. Evans, V.N. Rampton, and G.J. Woodsworth
1995 Improved Age Estimates for the White River and Bridge River Tephra, Western Canada. *Canadian Journal of Earth Sciences* 32(8):1172–1179.
- Crow, John R., and Philip R. Obley
1981 Han. In *Handbook of North American Indians*, vol. 6, *Subarctic*, edited by June Helm, pp. 506–513. Smithsonian Institution Press, Washington, D.C.
- Dixon, E. James, William F. Manley, and Craig M. Lee
2005 The Emerging Archaeology of Glaciers and Ice Patches: Examples from Alaska's Wrangell–St. Elias National Park and Preserve. *American Antiquity* 70(1):129–143.
- Esdale, Julie
2008 A Current Synthesis of the Northern Archaic. *Arctic Anthropology* 45(2):3–38.
- Froese, Duane G., Derald G. Smith, and David T. Clement
2005 Characterizing Large River History with Shallow Geophysics: Middle Yukon River, Yukon Territory and Alaska. *Geomorphology* 67:391–406.
- Froese, Duane G., Derald G. Smith, John A. Westgate, Thomas A. Ager, Shari J. Preece, Amanjit Sandhu, Randolph J. Enkin, and Florence Weber
2003 Recurring Middle Pleistocene Outburst Floods in East-Central Alaska. *Quaternary Research* 60(1):50–62.
- Guccione, Margaret J.
2008 Impact of the Alluvial Style on the Geoarchaeology of Stream Valleys. *Geomorphology* 101:378–401.
- Guccione, Margaret J., Michael C. Sierzchula, Robert H. Lafferty III, and David Kelley
1998 Site Preservation along an Active Meandering and Avulsing River: The Red River, Arkansas. *Geoarchaeology* 13(5):475–500.
- Hammer, T. J., and Thomas, C. D.
2006 *Archaeology at Forty Mile/Ch'ëdä Dëk*. Tr'ondëk Hwëch'in and Yukon Heritage Resources, Dawson City, YT.
- Hare, P. Gregory, Thomas J. Hammer, and Ruth M. Gotthardt
2008 The Yukon Projectile Point Database. In *Projectile Point Sequences in Northwestern North America*, edited by R.L. Carlson and M.P.R. Magne, pp. 321–332. Archaeology Press, Publication no. 35, Department of Archaeology, Simon Fraser University, Burnaby, BC.
- Hare, P. Gregory, Christian D. Thomas, Timothy N. Topper, and Ruth M. Gotthardt
2012 The Archaeology of Yukon Ice Patches: New Artifacts, Observations, and Insights. *Arctic* 65(5):118–135.
- Hoffecker, John F.
1988 Applied Geomorphology and Archaeological Survey Strategy for Sites of Pleistocene Age: An Example from Central Alaska. *Journal of Archaeological Science* 15(6):683–713.
- Hoffecker, John F., and Scott A. Elias
2003 Environment and Archeology in Beringia. *Evolutionary Anthropology* 12:34–49.
- Holmes, Charles
2001 Tanana Valley Archaeology circa 14,000 to 9,000 BP. *Arctic Anthropology* 38(2):154–170.
- 2012 The Beringian and Transitional Periods in Alaska: Technology of the East Beringian Tradition as Viewed from Swan Point. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 179–191. Texas A&M University Press, College Station, TX.
- Lerbekmo, J. F.
2008 The White River Ash: Largest Holocene Plinian Tephra. *Canadian Journal of Earth Sciences* 45(6):693–700.

- Lerbekmo, J. F., and F.A. Campbell
 1969 Distribution, Composition, and Source of the White River Ash, Yukon Territory. *Canadian Journal of Earth Sciences* 6:109–116.
- Livingston, Joanne M., Derald G. Smith, Duane G. Froese, and Chris H. Hugenholtz
 2008 Floodplain Stratigraphy of the Ice Jam Dominated Middle Yukon River: A New Approach to Long-Term Flood Frequency. *Hydrological Processes* 23(3):357–371.
- Mason, Owen K., and James E. Beget
 n.d. Re-evaluating the Age of the North Lobe of the White River Tephra. Unpublished manuscript on file, National Park Service, Fairbanks.
- Mishler, Craig, and William E. Simeone
 2004 *Hän, People of the River: Hän Hwëch'in: An Ethnography and Ethnohistory*. University of Alaska Press, Fairbanks.
- Reimer, P.J., M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, C.J.H. Bertrand, P.G. Blackwell, C.E. Buck, G.S. Burr, K.B. Cutler, P.E. Damon, R.L. Edwards, R.G. Fairbanks, M. Friedrich, T.P. Guilderson, A.G. Hogg, K.A. Hughen, B. Kromer, F.G. McCormac, S.W. Manning, C.B. Ramsey, R.W. Reimer, S. Remmele, J.R. Southon, M. Stuiver, S. Talamo, F.W. Taylor, J. van der Plicht, and C.E. Weyhenmeyer
 2004 IntCal04 Terrestrial Radiocarbon Age Calibration, 26–0 ka BP. *Radiocarbon* 46:1029–1058.
- Robinson, Stephen D.
 2001 Extending the Late Holocene White River Ash Distribution, Northwestern Canada. *Arctic* 54(2): 157–161.
- Slobodin, Richard
 1981 Kutchin. In *Handbook of North American Indians*, vol. 6, *Subarctic*, edited by June Helm, pp. 514–532. Smithsonian Institution Press, Washington, D.C.
- Thorson, Robert M.
 1982 Air-photo Reconnaissance of the Quaternary Landforms of the Yukon-Charley Rivers National Preserve, Alaska. Unpublished manuscript on file, National Park Service, Fairbanks.
- Weber, F.R.
 1986 Glaciation of the Yukon-Tanana Upland. In *Glaciation in Alaska—The Geologic Record*, edited by T.D. Hamilton, K.M. Reed, and R.M. Thorson, pp. 79–98. Alaska Geological Society, Anchorage.
- West, Frederick Hadleigh, Hans-Georg Bandi, and James V. Mathews
 1965 Archaeological Survey and Excavations in the Proposed Rampart Dam Impoundment, 1963–1964. Report to the University of Alaska and the National Park Service, contract no. 14-10-04340948 and 14-10-043401546 between UAF and NPS, Fairbanks.
- Workman, William
 1978 Prehistory of the Aishihik-Kluane Area, Southwest Yukon Territory. Mercury Series, Archaeological Survey of Canada Paper, 74. Ottawa: National Museums of Canada.

RETURN WITH A SHARING: COMING HOME TO THE KUSKOKWIM

Chris Wooley

Chumis Cultural Resource Services, 2073 Dimond Drive, Anchorage, AK 99507; chumis@gci.net

Evelyn Thomas

Crooked Creek Traditional Council, Crooked Creek, AK

BACKGROUND

Repatriation issues have presented difficulties for scientific institutions in recent years. Below, we discuss a repatriation case involving the remains of a woman that were removed from Crooked Creek, Alaska, by Aleš Hrdlička in 1930. Repatriation is the process by which museums and other institutions transfer possession and control of Native American, Alaska Native, and Native Hawaiian human remains, funerary objects, objects of cultural patrimony and sacred objects back to the tribes of origin (NMNH 2009). Despite the fact that different cultures treat human remains differently, and knowing that the inevitable bureaucratic hassles are going to be encountered, it is gratifying to know that progress is being made. The National Museum of Natural History (NMNH) staff of the Smithsonian Institution treated the authors fairly and reacted sensitively to a situation that might otherwise have been uncomfortable. The museum's Repatriation Office appears to have seized the opportunity to bring the interests of science and the Native community together as hoped fifteen years ago:

For all the controversy that surrounds repatriation in general, there still remains a need for increased communication between and sensitivity towards the different parties affected. There exists a unique opportunity to create a common ground of understanding, one that hopefully will be the ultimate legacy of repatriation at the Smithsonian and in the Nation as a whole (Zeder 1994:171).

We also acknowledge a simple suggestion Gordon Pullar made to the Larsen Bay Tribal Council in 1986 after learning of the simmering local resentment over Aleš Hrdlička's collection of human remains from Kodiak Island:

As I listened to the stories of Hrdlička's activities, my naïve response was to ask if a request had ever been made to the Smithsonian to return the skeletons and artifacts....I could not imagine at that time the chain of events that this request would generate (Pullar 1994:18).

The repatriation described in this paper means that the chain of events Pullar's words generated is still playing out. We acknowledge those who have supported this repatriation, which involved the remains of one woman. We trust that the words spoken to the woman on March 19, 2009, during the re-interment made their way across to her, along with the sharing, and brought her peace and rest.

STALKING HRDLIČKA

Everywhere and at all times [Hrdlička] indulged in his absorbing passion for collecting knowledge and potential new data in the form of specimens. To the very last of his field-trips he derived the keenest happiness from every new skull which he could carry back to his boat to be added to the thousands of others he had already amassed at home (Schultz 1944:314).

Much of my [CW] familiarity with the life and work of Aleš Hrdlička comes from visiting places he investigated in his scientific quest to understand the human physiology of race. Known as the “father of physical anthropology” (NAA 1996:4), he was one of the first to propose that Native Americans had their genetic origins across the Bering Strait in Asia (i.e., Hrdlička 1912). In an effort to prove his theory, he observed, measured, excavated and collected his way across Alaska between 1926 and 1938.

I initially encountered Hrdlička’s long reach near the Chukchi Sea while working for the North Slope Borough’s Inupiat History, Language and Culture Commission (IHLC). IHLC and the elders reinterred human remains that I salvaged on their behalf from an eroding site along Nunavak lagoon south of Barrow. The site was originally disturbed and collections made of human remains there in the early 1920s, with Hrdlička’s input (Wooley 1989). Over the years I have visited dozens of archaeological sites in Alaska—on the North Slope, in the Kodiak Archipelago, on the Alaska Peninsula, in the Aleutian Islands and along the Kuskokwim River—that Hrdlička initially described and where he often collected “specimens.”

It can be a challenge to show up in a rural Alaskan village where Hrdlička was the first anthropologist to do fieldwork. He made a lasting first impression. In the Aleutians he was “Dead Man’s Daddy” (Starn 2004:180); around Kodiak people knew him as “Hard Liquor” (Harper 1986:91); at Crooked Creek he was “the Skull Doctor” and local boogeyman. Almost everywhere I’ve done fieldwork in Alaska, Aleš Hrdlička was there first—and he has not been forgotten. Even among anthropologists he continues to be known for his “Prussian arrogance” and his “gruff and belligerent manner of dealing with native peoples” (Fitzhugh 1994:viii).

Local suspicion of outsiders is a fact of rural Alaskan life. A heightened level of suspicion of archaeologists is partly based on a community’s past experience with collectors like Hrdlička whose accessioning ends justified their means. While we can’t judge early twentieth-century mores by using twenty-first-century principles, the legacy of those initial investigations can’t be escaped or ignored. I’ve felt their impact firsthand. More than once, after being introduced as an archaeologist to a local tribal member, I’ve been asked, only partly in jest, something like “So, are you here to steal our bones?” Such comments are wry reminders that I was following in the footsteps of an archaeologist who had treated Alaska Natives as second-class citizens.

The comments also caused me to reflect that just a short time ago leading scientists thought that Euro-American Caucasians were the pinnacle of evolution, the template against which so-called lesser members of the human race should be judged. Having myself been the “minority” while living in inner-city Cincinnati, British Columbia Indian reserves, and the Inupiaq community in Barrow, I knew the fallacy of those views. Human worth cannot be measured by skull type and skin color, but just a couple of generations ago many believed otherwise.

In the early 1980s, before I worked in Alaska, I did my master’s research on the west coast of Vancouver Island, British Columbia. At that time, repatriating traditional cultural property, including ceremonial dance regalia from Canadian museums, to their First Nation descendants was accepted by the Canadian anthropologists with whom I worked. However, when I began my professional career in Alaska in the mid-1980s, repatriation was more controversial. U.S. researchers seemed to be having a difficult time adjusting to the prospect of returning collections compared to our Canadian colleagues (see, e.g., Bray and Killion 1994).

The Native American Graves Protection and Repatriation Act (NAGPRA) was passed in 1990 and formalized the repatriation process.¹ Among other things, it guides the process of how to treat human remains that might be encountered on certain cultural resource management projects. A single law didn’t instantly bring into balance the often competing interests between Natives and non-Natives, or between studying the past and addressing present needs. However a positive result of NAGPRA has been the respect that contemporary tribal rights and Native corporation interests are given in environmental impact statement (EIS)-mandated resource management work. Although indigenous people and western scientists can have different worldviews, NAGPRA, and other similar legislation, has helped foster a climate of mutual respect.

This paper is not about NAGPRA, or even about Aleš Hrdlička. Hrdlička put his version of the story into print in his *Alaska Diary* (Hrdlička 1943). Our current story is of a successful repatriation of human remains that Hrdlička took from Crooked Creek on the Kuskokwim River in 1930. The woman’s remains were given back by the Smithsonian and she was reinterred by the Crooked Creek Traditional Council (CCTC) on March 23, 2009. We present and examine the local version of events—the

oral tradition in which “the Skull Doctor” is still depicted as the boogeyman, and describe how Yup’ik and Athabaskan worldviews continue to structure life along the Middle Kuskokwim River.

THE SKULL DOCTOR OF CROOKED CREEK

While working on archaeological surveys of the Donlin Creek Mine in 2006,² Wooley had the opportunity to discuss with local tribal council representatives, including Evelyn Thomas of the Crooked Creek Traditional Council, the process of conducting archaeological survey of the project area. One of many important issues to address before doing archaeology in Alaska is how to treat human remains that might be encountered—either through archaeological survey and testing or inadvertently during other project activities.³

In corresponding with Evelyn in January 2007 about human remains protocols and other issues, Wooley asked if the council had been contacted by any museums that may have had human remains from their village. He had assumed the tribal council would have been contacted by whatever institution held the remains. Wooley had recently re-read Hrdlička’s *Alaska Diary* (Hrdlička 1943) and recalled a reference to Hrdlička taking remains from Crooked Creek:

June 30. Late last night opened an old grave on a trader’s place, but the bones lay frozen in hard ice, so I had to leave everything (Hrdlička 1943:323).

July 3. After noon arrive at Parents, Crooked Creek, examine some sick, and take out the frozen-in skeleton I had to leave here before. Even now however must use kettlefuls of hot water, carried from the few rods distant house, to loosen the bones. A female, skull fine type, small parts still in ice (Hrdlička 1943:328).

Evelyn and her husband, Dennis Thomas, and their family live at the actual site (Parent’s Trading Post) from which the remains were taken (Fig. 1). Sam Parent, who ran the trading post, was Evelyn’s father. The trading post may have originally been the site of a fall caribou hunting camp. According to Zagoskin (1967:265), who explored the area in 1844, a summer camp [named Kvikhchagpak] was located at the mouth of Crooked Creek [i.e., the Kvikhchagpak or Khottyln] and was occupied by people from Kwigumpainukamiut, a village near Kolmakovskiy Redoubt. It’s unclear where this camp was relative to

Crooked Creek, though cultural materials eroding from an early historic Native site upriver from the mouth of the creek, which were noted by Hrdlička (1943:328) may represent the summer camp that Zagoskin observed (Williams and Slayton 2006:14).

In subsequent phone discussions, Evelyn described the local oral tradition about Hrdlička’s 1930 visit, and also talked passionately about how he had caused the woman’s suffering in the afterlife, and what that implied for the local community. Wooley had seen an index of audiotaped elder interviews from the 1980s on file at the National Park Service that mentioned a visit from “the Skull Doctor”—presumably a taped version of the oral account that Evelyn related to Wooley in phone conversations. Evelyn was very concerned that the remains had been taken over local objections, that they were possibly in the NMNH, and that the woman’s spirit was not at rest. She expressed great interest in having the remains returned in order to set things right.

Wooley wrote to David Hunt, the manager of the physical anthropology collections at the NMNH, who searched their records and found that the remains Hrdlička had collected from Crooked Creek were still in the Smithsonian collection (cat. no. P351322). According to Hunt, Hrdlička collected one set of human remains that included a cranium, mandible, and some post-cranial elements; he determined that the remains were those of a female. Dr. Hunt determined the likely age of the remains based on prior examination by Smithsonian physical anthropologists and noted in an e-mail: “The sites that were excavated were considered to be “modern” or late period by both Hrdlička as well as by Henry Collins in his assessment in the 1960s.”

Wooley realized that repatriating the remains was the proper thing to do, and discussed the issue with Nick Enos and Stan Foo of Barrick (now Donlin Gold) during a July 2007 project planning meeting. They supported Wooley’s proposal to help the Crooked Creek Traditional Council work with the Smithsonian to get the remains of the woman returned to Crooked Creek so they could be reinterred.

The NMNH Repatriation Office started a process of scientific documentation of the human remains once the CCTC requested their assistance. A Smithsonian tribal travel grant funded two CCTC representatives—Evelyn and Dennis Thomas—to go to Washington and bring back the remains. Barrick supported Wooley’s continued assistance with the logistics of the repatriation as well



Figure 1. Map showing location of trading post. Cross-hatching indicates approximate extent of the modern community of Crooked Creek.

as research into pertinent portions of Hrdlička's collections, field notes and photographs on file at the National Anthropological Archives facility in Suitland, Maryland.

In September 2007, Wooley helped Evelyn Thomas draft a repatriation request to Dorothy Lippert of the Smithsonian Repatriation Office. Evelyn discussed with the family and the tribal council the possibility of having DNA analysis of the remains done to try and determine if the woman was a family member, since she could have been Evelyn's great-aunt or great grandmother. While members of the CTCC were upset that the remains had been removed originally, they did not object to Evelyn's suggestion that DNA analysis be conducted.⁴ The unanimous decision of the council was to request that the in-

dividual's remains be returned to the family cemetery at Crooked Creek.

Evelyn submitted the formal request from the CCTC in November 2007 and heard back from the Smithsonian in 2008 that it was under consideration. The NMNH staff examined and analyzed the remains and decided to repatriate them. The requisite notice in the Federal Register occurred, a travel grant was made to the CCTC, and in March 2009 Wooley accompanied Evelyn and Dennis Thomas on a trip from Alaska to Washington, DC, where the remains were officially turned over to CCTC. The remains were reinterred in the Crooked Creek cemetery on March 19, 2009, with a Russian Orthodox ceremony led by David John.

In my opinion, there is a real possibility that the remains Hrdlička collected at Crooked Creek were from a mid-nineteenth-century Russian Orthodox burial. As it turns out, there was some green staining on one of the thoracic vertebrae. In an e-mail to Wooley from September 2008, Dorothy Lippert noted that the stain was consistent with a single metal object placed on the chest:

Since it's such a small spot and very localized, I'm thinking that it's from a single metal object that would have been placed on the chest. Possibly from a small ornament of some kind. When I used XRF spectroscopy to examine the green stain, I got a reading that's high in zinc, but less so in copper.

When I discussed this issue with physical anthropologist Joan Dale of the Alaska Office of History and Archaeology, she almost immediately recognized the stain as the imprint that a Russian Orthodox cross would have left. Donna Redding-Gubitosa (1992:111) described the impact of Russian Orthodoxy in the region by the 1850s and specifically at the Kwigiumpainukamiut site, downstream from Crooked Creek and across the river from Kolmakovsky Redoubt. Artifacts from the site included locally made molds used for making small Orthodox and Christian crosses, indicating the extensive use of these religious symbols in everyday life during the mid-1800s.

The anthropological aspects of this repatriation have been an interesting exercise in how the discipline of Alaska anthropology has evolved over the past century. The most rewarding aspect of the entire process has been getting to know Evelyn and Dennis Thomas and their large extended family, other residents of Crooked Creek, and members of the Smithsonian repatriation staff. It is also satisfying to know that the return and reburial of the unknown woman's remains have put things back in order for Evelyn and the Crooked Creek community.

MY RELATIVES AND OUR RELATIONS

The woman originally taken from Crooked Creek is potentially—I [ET] would say very likely—a direct family relative of mine. She was probably related to my family on my father's side. Being buried on our land in historic times demonstrates a close cultural affiliation. I know the location of the original site. There is some sheet iron around there now.

The location where Hrdlička dug was a well-used site long before my grandfather started the trading post, as evidenced by Zagoskin's 1844 account of a summer

camp there (e.g., Zagoskin 1967). There is archaeological evidence of use and occupation of this location dating to about AD 1600 from an excavation of an adjacent site (SLT-088) (Williams and Slayton 2006). We also know through my family's oral history that this place was used for quite some time.

My father was Sam Parent, who ran the trading post he inherited from my grandfather; my mother was the late Theresa (Morgan) Parent, who was born at Ohagamiut above Kalskag. My mother's mother was Mary Joe Peterson from Mountain Village. In my grandmother's time, they were digging—maybe a building or cellar—when the bones were exposed. It was left open, and Hrdlička waited until people were gone to collect the bones. He finished his trip up the Kuskokwim to Stony River, and stopped back in at Crooked Creek later in the summer when people were dispersed at fish camps. He made sure most people were gone so he could more easily collect the bones. The story is that he pushed my grandmother aside when she angrily tried to stop him. According to my late aunt, the woman whose bones were taken was a member of my paternal grandfather's family. My family is still tied to this land, and by virtue of my continued association with this land, I am tied to the bones of my ancestors.

After that experience my great aunt, Sophie Sakar, used to call Hrdlička "the skull doctor"—he was the local boogeyman. Kids were told to behave or else he'd come and take their heads. I remember being frightened at the thought. One time, not long afterwards, a white man came over to me and picked me up off the floor—he was the first outsider I had seen since hearing the Skull Doctor story. I was terrified because I thought for sure some recent misbehavior had been found out and that he was going to pack me away!

If, as I suspect, the woman was my relation through my paternal grandfather's family, she would have been Athabaskan—Ingalik or perhaps a Dena'ina speaker. My grandmother was Massa Effemka, who died of tuberculosis around 1938–1939. Massa's father, my great grandfather, was Essemka or "Big Whiskers"—we don't know his English name. Massa's sister was Sophie Sakar. Her Indian name was Timkook, meaning "walking on the sides of her shoes." Apparently her mukluk bottoms were made such that it caused her to walk that way. Sophie, who died of tuberculosis in 1968, had taught me a lot about traditional ways and we were very close. I called her my "ulla," an affectionate and respectful term in Yup'ik.

When I heard the woman's bones were in the Smithsonian, I suspected that the removal of her body might help explain some of what has happened in Crooked Creek. Her spirit was wandering and angry. I sometimes couldn't figure out why certain things had been happening the way they were, but in hindsight, this may help explain it. Some events had occurred in the community that led us to believe that the person's spirit was wandering and unsettled. These events are of a somewhat personal nature to the community, but in general they involved what could be described as paranormal experiences including vivid dreams of a white man with flowing white hair accompanied by a subdued Native woman with a hole in her cheek. That man came to me in some unsettling dreams and said he owned something of ours. A number of other disturbing events occurred in and near the trading post.

I left the village in 1963 and went to school in Anchorage and Copper Center. When I returned some ten years later, major changes were happening due to the passage of ANCSA (Alaska Native Claims Settlement Act) and other events. I couldn't quite understand what my role should be, and when I spoke to the elders and they told me in time I would know. Back then, I didn't know what I was looking for. Then I inherited the family home, and continue to feel a strong connection to family and the community. By doing this repatriation I'm trying to help make things right, as best I can. This has been a way to set something right.

Dorothy Lippert of the Smithsonian's Repatriation Office was very helpful and was committed, both as a professional and a Native American woman, to help with the return. She understood and would tell the woman she was coming home, and helped so much in many other ways. Dorothy let me know that if we could show the remains were of my direct ancestor, the case would be expedited. I couldn't help but say how ironic it was that Hrdlička didn't have any problem taking them away, but we had to jump through a bunch of hoops to get them back!

Chris Wooley helped explain it would take time, but after what I thought was plenty of time—over a year—I put in a call to Alaska Senator Ted Stevens' office. As it turned out, one of the last acts in his long career as an Alaska senator was to ask the director of the repatriation office, Bill Billeck, about the case's status, thereby helping set a high priority for the repatriation. So many people were helpful and I'm pleased that they rewarded our hope that she would be returned and come home.

When we came to Washington, DC, we brought small bits of earth, wood and pieces of local food that we burned in a short ceremony when I first got to be in the room with her. We call that *avugbuk*, which roughly translates as "a sharing." It was kind of like an offering—it was a way to communicate with her by letting her know that everything was going to be okay and that we were going to bring her home. The elders instructed us to do this, and it was the right thing to do. As we brought her back to Alaska, the box she was in kept getting lighter and lighter. We know that she is at peace now and the strange things that were happening in Crooked Creek have stopped. It was such a relief when we reburied her—and it still is.

ACKNOWLEDGMENTS

We acknowledge the assistance of the Crooked Creek Traditional Council (CCTC), the Repatriation Office at the Smithsonian's National Museum of Natural History (NMNH), and Donlin Gold LLC. The kind and professional support of these individuals is greatly appreciated: the community of Crooked Creek, Alaska, especially the Thomas family; Nick Enos, James Fueg and Stan Foo of Donlin Gold LLC; Dorothy Lippert, Greg Anderson, Bill Billeck, Chris Dudar, Erica Jones, David Hunt and Sarah Feinstein of the Repatriation Office at the NMNH; Josh Reuther, Molly Proue and the staff of Northern Land Use Research, Inc.; the late Senator Ted Stevens; Dennis O'Rourke of the University of Utah; and Dave McMahan and Joan Dale of the Alaska Office of History and Archaeology.

NOTES

1. For the museums that comprise the Smithsonian Institution, the National Museum of the American Indian (NMAI) Act, passed in 1989 and amended in 1996, governs repatriation. The Native American Graves Protection and Repatriation Act (NAGPRA) directs repatriation for other U.S. institutions that receive federal funding (NMNH 2009).
2. Northern Land Use Research, Inc., and Chumis Cultural Resource Services have worked together on the Donlin Gold project since 2004, conducting cultural resource management for the project and community archaeology in Crooked Creek. Crooked

Creek is a village whose inhabitants are primarily of Central Yup'ik and Ingalik Athabaskan heritage.

3. No human remains have been identified in or near the proposed project area as of the end of the 2011 field activities.
4. Wooley contacted Dennis O'Rourke of the University of Utah, an expert at ancient DNA analysis and Alaska Native populations, who was willing to assist; however, in the end, DNA analysis was not conducted because of contamination concerns.

REFERENCES

- Bray, Tamara L., and Thomas W. Killion, eds.
1994 *Reckoning with the Dead: The Larsen Bay Repatriation and the Smithsonian Institution*. Smithsonian Institution Press, Washington, DC.
- Fitzhugh, William
1994 Foreword. In *Reckoning with the Dead: The Larsen Bay Repatriation and the Smithsonian Institution*, edited by Tamara L. Bray and Thomas W. Killion, pp. vii–x. Smithsonian Institution Press, Washington, DC.
- Harper, Kenn
1986 *Give Me My Father's Body: The Life of Minik, the New York Eskimo*. Steerforth Press, South Royalton, VT.
- Hrdlička, Aleš
1912 *Early Man in South America*, in collaboration with W.H. Holmes, B. Willis, F.E. Wright, and C.N. Fenner. Bulletin of the Bureau of American Ethnology no. 102:1–405. Government Printing Office, Washington DC.
- 1943 *Alaska Diary, 1926–1931*. Jacques Cattell Press, Lancaster, PA.
- National Anthropological Archives (NAA)
1996 Register to the Papers of Aleš Hrdlička. National Anthropological Archives, Suitland, MD.
- National Museum of Natural History (NMNH)
2009 What Is Repatriation? Repatriation Office website. <http://anthropology.si.edu/repatriation/whatis/index.htm> Accessed March 30, 2009.
- Pullar, Gordon
1994 The Qikertarmiut and the Scientist: Fifty Years of Clashing World Views. In *Reckoning with the Dead: The Larsen Bay Repatriation and the Smithsonian Institution*, edited by Tamara L. Bray and Thomas W. Killion, pp. 15–25. Smithsonian Institution Press, Washington, DC.
- Redding-Gubitoso, D.
1992 Excavations at Kwigiumpainukamiut: A Multi-Ethnic Historic Site, Southwestern Alaska. Ph.D. dissertation, Department of Anthropology, University of California, Los Angeles.
- Starn, Orin
2004 *Isbi's Brain: In Search of America's Last "Wild" Indian*. Norton, New York.
- Schultz, Adolph H.
1944 Biographical Memoir of Ales Hrdlicka 1869–1943. Paper presented to the Academy at the Autumn Meeting, 1944. National Academy of Sciences of the United States of American Biographical Memoirs no. 12, vol. XXII.
- Williams, C. M., and L. J. Slayton
2006 Cultural Resource Survey of Proposed Sewer and Water Improvements, Crooked Creek, Alaska. Report prepared for Alaska Native Tribal Health Consortium by Northern Land Use Research, Inc., Fairbanks.
- Wooley, Chris B.
1989 *Nunavak Lagoon Burial Knoll Erosion Mitigation*. Report on file at Ukpeagvik Inupiat Corporation, Barrow, and State of Alaska Office of History and Archaeology, Anchorage.
- Zeder, Melinda
1994 Repatriation at the National Museum of Natural History, Present and Future. In *Reckoning with the Dead*, edited by Tamara L. Bray and Thomas Killion, pp. 166–174. Smithsonian Institution Press, Washington, DC.
- Zagoskin, Lavrentiy
1967 *Lieutenant Zagoskin's Travels in Russian America, 1842–1844: The First Ethnographic and Geographic Investigations in the Yukon and Kuskokwim Valleys of Alaska*, edited by Henry N. Michael; translated from Russian by Penelope Rainey. University of Toronto Press, Toronto.

REVIEW

THE ARCHAEOLOGY OF NORTH PACIFIC FISHERIES

Edited by Madonna L. Moss and Aubrey Cannon, 2011. University of Alaska Press, Fairbanks. Paper, 320 pages, photos, line drawings, maps, tables, index. ISBN: 978-1-60223-146-7; \$45.00

Reviewed by Michael A. Etnier

Applied Osteology, P.O. Box 92, Bellingham, WA 98227-0092; michael.etnier@applied.osteology.com

As the editors of *The Archaeology of North Pacific Fisheries* point out in their introduction (p. 6), zooarchaeological analysis of fish remains is a relatively young field of study, with only a few decades of specialized attention in the eastern North Pacific. The contributions to this volume, though just a sampling of the work currently being conducted around the eastern North Pacific, highlight the depth and range of approaches that characterize the state-of-the-art in the zooarchaeological analysis of fish remains.

For better or for worse, many of the papers retain their conference-presentation flavor—generally long on introductions and background, short on data and interpretations. But this is part of what makes the contributions to this volume so appealing—they offer concise glimpses of each contributor's particular research interests, some of which have been developing for decades. Each chapter has its own list of references, which allows for easy follow-up and cross-referencing.

Zooarchaeologists are still struggling with fundamental issues that have plagued fish bone analyses from day one: density-mediated destruction of bone, recovery bias, and taxonomic identification. Many of the chapters in this volume detail innovative approaches to these challenges. Smith, Butler, Orwoll and Wilson-Skogen (Chapter 4), for instance, add an important body of data that allows for an evaluation of survivorship of cod (*Gadus macrocephalus*) bones relative to those of salmon (Salmonidae). In my opinion, the possibility of density-mediated destruction of bone should be evaluated for every assemblage analyzed, regardless of the apparent state of preservation. As more

and more taxa are added to the list for which we have bone density data, our ability to understand how time has structured our assemblages will only improve.

Of course, none of this matters if we continue to use recovery methods that we know (and have known for decades) significantly bias against smaller-bodied taxa and against small skeletal elements of large-bodied taxa. Recognizing that we cannot use the same excavation and recovery strategies to sample for all classes of faunal remains, Cannon, Yang and Speller have developed a sampling protocol that uses bucket augers to recover large spatially and temporally representative samples of fish bones from shell middens (Chapter 5; see also Cannon 2000; Caldwell, Chapter 14; Brewster and Martindale, Chapter 15). Cannon et al.'s approach seems to solve many of the problems associated with traditional excavation and recovery methods, providing a nice balance between cost-effectiveness, degree of site destruction, and recovery of faunal remains. However, I think that a combination of intensive sampling for fish and extensive sampling for other classes, such as mammals, will ultimately be necessary for understanding the full range of subsistence activities represented at any given site.

With these relatively recently developed tools for (a) recovering a representative sample of an assemblage and (b) evaluating the degree to which density-mediated attrition of bone has structured that sample, there still remains the problem of species-level identification—a problem felt most acutely in the analysis of salmon remains. Several approaches are advocated in this volume,

ranging from circumstantial evidence based on locations of sites (e.g., Prince, Chapter 7), to combinations of metric, radiographic, and isotopic analyses (Orchard and Szpak, Chapter 2; Orchard, Chapter 8), to the relatively expensive, but extremely effective use of genetic analyses (Cannon et al., Chapter 5).

None of these approaches is perfect—the analyses advocated by Orchard are not 100% reliable, and the uncertainty appears to be higher in areas geographically distant from where Orchard developed and tested the approach. And while DNA-based identifications can be expected to be reliable when they are derived in meticulously maintained ancient DNA labs, it is not feasible to submit a full assemblage for such analyses. As with Cannon et al.’s balanced approach to sampling midden sites for fish bones, a combination of the approaches described here will probably yield the most consistent and reliable results.

Even if we some day reach a point where we can identify the majority of fish remains with certainty, I think it is unlikely that zooarchaeologists will ever be able to divine the subtle and sophisticated nuances of fish selectivity documented by Elroy White in his interviews with Heiltsuk elders (Chapter 6). Not too long ago, fish biologists discouraged archaeologists from even *looking* for salmon remains, because of the mistaken belief that the cartilaginous nature of much of their skeletons would ensure their complete destruction in burial contexts (Moss and Cannon, Chapter 1). Of course, we now know that the remains of even strictly cartilaginous fishes, such as ratfish (*Hydrolagus collieri*) and spiny dogfish (*Squalus acanthias*), are routinely recovered from archaeological sites (Monks, Chapter 9; Caldwell, Chapter 14; Trost, Schalk, Wolverton and Nelson, Chapter 16), along with the nearly ubiquitous assemblages of salmon vertebrae and cranial bones. Who knows what sorts of questions we will be able to address with fish bones if we simply devise new ways to look for the answers?

Although much of the general public is not yet aware of it, I think it is safe to say that archaeologists working in the eastern North Pacific have finally found the correct prescription for overcoming decades of collective “salmon-opea” (cf. Monks 1987). However, we still have a long way to go. First and foremost, all of the chapters in this volume share a general goal of developing a deeper understanding of the cultural, spiritual, and caloric importance of fish to peoples both ancient and modern living on the Pacific Coast. Efforts by Betts, Maschner and Clark (Chapter 11) and Moss, Butler and Elder (Chapter 17) clearly show the potential of archaeofaunas in general, and fish remains in particular, to contribute to a larger goal of informed natural resource management. The potential for zooarchaeology is still growing and at an unprecedented pace, as the contributions to Moss and Cannon’s *The Archaeology of North Pacific Fisheries* demonstrate.

REFERENCES

- Cannon, Aubrey
2000 Assessing Variability in Northwest Coast Salmon and Herring Fisheries: Bucket-Auger Sampling of Shell Midden Sites on the Central Coast of British Columbia. *Journal of Archaeological Science* 27:725–737.
- Monks, Gregory G.
1987 Prey as Bait: The Deep Bay Example. *Canadian Journal of Archaeology* 11:119–142.
- Moss, Madonna L., Kathleen Judd, and Brian Kemp
2012 Tlingit Salmon Use at Coffman Cove: Determining Salmon Species using Morphometric vs. Ancient DNA. Paper presented at the 39th Annual Alaska Anthropological Association meeting, Seattle, WA.

REVIEW

ULTIMATE AMERICANS: POINT HOPE, ALASKA, 1826–1909

by Tom Lowenstein, 2008. University of Alaska Press, Fairbanks. Paperback, xxx + 351 pp., three maps, 38 figures, three appendices, index; ISBN 978-1-60223-038-5; \$36.95

Reviewed by Mark S. Cassell

Territory Heritage Resource Consulting, 200 W. 34th Ave., Anchorage, AK 99503; territory.heritage@gmail.com

Tom Lowenstein's edifying and eloquent *Ultimate Americans: Point Hope, Alaska, 1826–1909* is the third in a series of presentations resulting from his 1973–1989 oral historical and archival research into the social, spiritual, technological, material, and historical milieu of the traditional Northwest Alaska Iñupiaq Eskimo whaling culture as seen from the environs of Point Hope (see also Lowenstein 1992, 1993). Known as Tikigaq in its pre-European days, this millennia-old settlement on the Chukchi Sea coastline was a perfect resource extraction locale for traditional subsistence hunting of the bowhead whale and for subsequent industrial harvests in the late nineteenth and early twentieth centuries following decimation of whale populations by commercial pelagic whalers in the western Arctic fishery. This well-illustrated, ably researched, and plainly written volume walks us through a history of the place from initial direct Iñupiaq and European contact in the early nineteenth century, through sustained Iñupiaq/EuroAmerican social and material relations in the mid-late 1800s, and into early twentieth century events figuring prominently in building contemporaneous and near-future historical landscapes.

Lowenstein understands local manifestations of the triumvirate of EuroAmerican colonialist agents: the state, commerce, and missions (e.g., Fabian 1990). In late nineteenth- and early twentieth-century Point Hope, the state was represented by the U.S. Bureau of Education, which imposed a Native Alaska schooling plan managed by Christian missions and introduced and managed the Native reindeer industry, and by the U.S. Revenue

Cutter Service, which provided American law and order in this recently acquired colony. The role of commerce was played by the numerous commercial shore whaling and trading entities at the nearby shore whaling enclave at Jabbertown, which employed regional (but not local) Iñupiat as shore whaling crews and offered an enormous variety of EuroAmerican manufactured goods for trade and as partial remuneration for Native labor. Mission involvement was provided at Point Hope by the Episcopal Church and its Domestic and Foreign Missionary Society, and in Alaska more generally by Sheldon Jackson, the Presbyterian missionary appointed by the federal government to plan and direct Alaska Native education and reindeer herding programs.

In Point Hope (and elsewhere in contemporary Northwest Alaska), the intermingling of these institutional agents could be remarkably convoluted. The Episcopal Church was contracted by the Bureau of Education in 1889 to operate the new school. Dr. John Driggs was the Episcopalian missionary in Point Hope from 1890 to 1908; this medical doctor was also the schoolteacher, a trader running a shore whaling crew, and a gold prospect claimant. The Revenue Cutter *Bear* patrolled the coastline, managing order amongst the cosmopolitan Jabbertown whaling crowd, meting out justice and supplies, as appropriate. (These circumstances are reminiscent of the long tenure at Point Barrow of Charles Brower, a whaler, trader, and federal appointee, and Driggs' contemporary.)

While institutional colonial agents endeavored to bring social and behavioral Americanization to the people

of Point Hope, local Inupiaq forces served to maintain a traditional community in the face of colonial development. This included maintaining traditional Inupiaq structures of power and the control over people and resources held by shamans and *umialiit* (whaling captains). The powerful Point Hope *umialik* Ataauraq, together with shamans, forbade shore whalers to establish stations in Point Hope proper, hence the founding of Jabbertown. Ataauraq profited handsomely through trade with commercial operators and retained his local Native whaling crews. Point Hope people refused to work for Jabbertown whalers (but they worked for other American whaling interests in the region, such as Brower's outfit). Local *qalgi* (traditional "men's houses") used in spiritual and subsistence whaling tasks were sustained (thanks in part to a sympathetic Driggs; they were destroyed after Driggs' 1909 removal and subsequent replacement by the generally unsympathetic Rev. Hoare). Inupiaq actions vis-à-vis EuroAmerican state, mission, and commercial interests in late nineteenth- and early twentieth-century Northwest Alaska present a fine historical example of social agency.

Lowenstein is a writer of poetry and spirituality and music; he is not a trained professional historian or anthropologist. This permits two observations. On the one hand, his grasp of historical materials and the scale and scope of the work are all the more remarkable given a background that does not ordinarily include such discipline-specific skill sets. On the other hand, his occasional editorial commentary and conjecture on historical goings-on are readily forgiven. As readers, we are aware that Lowenstein has the requisite research, compilation, and composition abilities, we know his sources, and we take his presentation not as *the* authority but as *one among a few* well-conceived and reasonably approached histories of the time and place.

Ultimate Americans is of interest and substantive use to professional, student, lay, and stakeholder audiences. Practitioners in Native studies, sociocultural anthropology, northern and maritime history, ethnohistory, and archaeology will appreciate its historical depth and breadth and the numerous and detailed primary source references. Lay readers will appreciate the book's fascinating topic and historical context and benefit from its clear prose and organization. Finally, and perhaps most importantly, a local and regional Inupiaq readership will gain from Lowenstein's consistent invocation and extensive use of oral histories conducted with a now-departed generation of Inupiaq elder knowledge bearers about this transformative period in the history of Point Hope in particular and

of Northwest Alaska in general. Useful and broader historical context for Point Hope and the Northwest Alaska region can be gleaned from reading *Ultimate Americans* in conjunction with Lowenstein (1992), Bockstoce (1986), Burch (1982), VanStone (1962), Larson (2004), Rainey (1947), Chance (1990), Brower (1994), Sheehan (1997), and Cassell (2000, 2004). *Ultimate Americans* is a good read, a worthy source, and a must-have addition to any serious Alaska history library.

REFERENCES

- Bockstoce, John R.
1986 *Whales, Ice, and Men: The History of Steam Whaling in the Western Arctic*. University of Washington Press, Seattle.
- Brower, Charles D.
1994 *Fifty Years Below Zero: A Lifetime of Adventure in the Far North*. University of Alaska Press, Fairbanks.
- Burch, Ernest S., Jr.
1982 *The Traditional Eskimo Hunters of Point Hope, Alaska: 1800–1875*. North Slope Borough, Barrow.
- Cassell, Mark S.
2000 'If They Did Not Work for the Station, They Were in Bad Luck': Commercial Shore Whaling and Inupiat Eskimo Labor in Late-Nineteenth/Early-Twentieth Century North Alaska. Ph.D. dissertation, Department of Anthropology, SUNY-Binghamton.
2004 Eskimo Laborers: John Kelly's Commercial Shore Whaling Station, Point Belcher, Alaska, 1891–1892. In *Indigenous Ways to the Present: Native Whaling in the Western Arctic*, edited by Allen P. McCartney, pp. 371–410. Canadian Circumpolar Institute, Calgary.
- Chance, Norman A.
1990 *The Inupiat and Arctic Alaska: An Ethnography of Development*. Holt, Rinehart and Winston, Fort Worth.
- Fabian, Johannes
1990 Religious and Secular Colonization: Common Ground. *History and Anthropology* 4(2):339–355.
- Rainey, Froelich G.
1947 The Whale Hunters of Tigara. *Anthropological Papers of the American Museum of Natural History* 41(2):231–283.

Larson, Mary Ann

2004 *The Evolution of the Qalgi in Post-Epidemic Point Hope, Alaska*. Ph.D. dissertation, Department of Anthropology, Brown University.

Lowenstein, Tom

1992 *The Things That Were Said of Them: Shaman Stories from Tikigaq, Alaska*. Told by Asatchaq. University of California Press, Berkeley.

1993 *Ancient Land, Sacred Whale: The Inuit Hunt and Its Rituals*. Farrar, Strauss, and Giroux, New York.

Sheehan, Glenn W.

1997 *In the Belly of the Whale: Trade and War in Eskimo Society: An Account of Politics, Ceremonialism, and Survival in Northern Alaska, AD 1200–1900*. Aurora Monograph Series, vol. 5. Alaska Anthropological Association, Anchorage.

VanStone, James W.

1962 *Point Hope: An Eskimo Village in Transition*. University of Washington Press, Seattle.

REVIEW

GWICH'IN ATHABASCAN IMPLEMENTS: HISTORY, MANUFACTURE, AND USAGE ACCORDING TO REVEREND DAVID SALMON

By Thomas A. O'Brien, 2011. University of Alaska Press, Fairbanks. Paperback, xxxii + 133 pages, 112 figures, two appendices, index. ISBN 978-1-60223-144-3; \$45.00

Reviewed by Norman Alexander Easton

School of Liberal Arts, Yukon College, Box 2799, Whitehorse, Yukon Territory, Canada, Y1A 5K4; northeaston@gmail.com

Gwich'in Athabascan Implements is the product of the fruitful collaboration of Reverend David Salmon with Tom O'Brien, who worked with Salmon for over ten years until Salmon's death in 2007 at the age of ninety-five. Born in 1912, Salmon was raised in the bush-land of the Wood River country by his father, William Salmon, who was concerned that life in the nearest village, Salmon, some hundreds of miles away, would prove too dangerous for his son during a time when contagious diseases ravaged the Alaska Interior.

Thus, for many years of his life, Salmon made a living with his father by trapping in a sparsely populated region where "my father tell me the story. We have no radio, we have no TV. Only I listen to my father... the only one talking all winter long for eighteen years. And I learned..." (p. xxix). As a result, Salmon was well-informed about his ancestors' traditional culture when he embarked on his own life in the modern Alaska that was emerging in the 1940s and 1950s.

Beginning in 1994, Salmon made a set of traditional Athabascan tools based on the teachings of his father and other elders. The tool set eventually grew to include implements associated with hunting, fishing, gaming, and manufacturing, as well as special purpose items. Thirty-eight of these tools, fifteen of which are arrows, are described in the text. The descriptions are based on a close examination of their morphological characteristics and supplemented by life-size drawings by O'Brien. The construction and contextual use of each artifact is further elaborated upon in the accompanying text, which was drawn directly from

a series of taped discussions with Salmon that were recorded by O'Brien in 1997.

In constructing the text, O'Brien "intentionally refrained from interjecting [his] own assumptions or citing comparative references from other sources," seeking only "to present this detailed body of knowledge solely reflecting the information as conveyed to me by Rev. Salmon" (p. xix). On the one hand, this approach allows for a respectful acknowledgement of Salmon's personal knowledge, but for some it will represent a major failing in that it represents a single, idiosyncratic perspective lacking traditional comparative ethnographic context.

I do not find this to be a major problem; many of the implements are well-known to Athabascan scholars and documented in traditional ethnographic sources. It is precisely Salmon's intimate knowledge of the implements that makes the book useful and interesting. His personal knowledge is extensive, including not only technology and construction techniques, but also the social context of the implements—who may make the object, who may use it, when and under what circumstances, and a description of the associated social norms and taboos. I particularly liked the account of the Grizzly Bear Spear; the description of how it was used to dispatch this dangerous northern resident was both chilling and awe-inspiring.

The main text is preceded by a short introduction to the Gwich'in Athabascan homeland, Salmon's life history, and reflections on the creation of the artifacts and the collaboration between O'Brien and Salmon. The five-page index is entirely adequate.

Many readers of the *Alaska Journal of Anthropology* will recall that in 2001 both O'Brien and Salmon were keynote speakers at our annual conference, held that year in Fairbanks and sponsored by the Tanana Chiefs Conference. O'Brien has thoughtfully chosen to include the text of Salmon's address that year, "A Clean History: How I Work with Other People." A wonderful example of Athabascan English oratory, Salmon reminded us of the unique collaborative relationship that typifies much of the interaction between Natives and non-Natives in the North, how through our shared history, Natives, traders, prospectors, trappers, and contemporary residents—including anthropologists—helped each other to survive in this sometimes harsh environment, creating "a clean history." Salmon also noted that "Indian too was anthropologist, you know from the early days. They study the people, they study the life of the animal, people through living things" (p. xxxii), an instructive observation that encourages me in the continued pursuit of this cross-cultural endeavor to which we devote ourselves.

REVIEW

ELDORADO! THE ARCHAEOLOGY OF GOLD MINING IN THE FAR NORTH

Edited by Catherine Holder Spude, Robin O. Mills, Karl Gurcke, and Roderick Sprague. 2011. University of Nebraska Press, Lincoln. Paper, 376 pages, B&W photos, maps, tables. ISBN: 978-0-8032-1099-8; \$55.00.

Reviewed by Dael A. Devenport

National Park Service, Anchorage, AK; dael_devenport@nps.gov

The image that comes to mind, probably for most people, when thinking of a gold rush miner is a bearded old sourdough sporting a flannel shirt, suspenders and floppy hat. Implied in this picture are the affiliated characteristics: tough as nails, antisocial, and dependent on no one. *Eldorado!* attempts to change this image by demonstrating the extensive transportation and supply network that the miners were dependent on, yet at the same time contributing to. The book focuses on placer mining sites and is divided into five sections.

The first section grounds the reader in the history, theory, model, methods, challenges and opportunities presented by gold rush archaeology. Robert L. Spude hooks the reader with the story of stamper Mattie Wilson and calls for a revision of the current understanding of the gold rush promoted by sensational writers such as Jack London and Robert Service from a lawless male-oriented frontier to one that includes families, order and economic networks. Hardesty's theoretical chapter identifies frontier mining as a cross-cultural type of community characterized by rapid change and flexibility in social structures, ideologies and technology.

Catherine H. Spude shares a multiple linear regression method helpful in determining the type of site using its artifact assemblage and comparing it to collections from other representative sites, such as saloons, brothels and family homes. Although she acknowledges that complex statistics are easy to "use, abuse and misunderstand" (p. 74), her words of advice to archaeologists are that "complex statistics are here to stay. It behooves the

researcher to learn them and what they can do for him or her" (p. 53). Spude's method is used by several authors in the volume. Purser discusses how information gained through gold rush archaeology can contribute to research outside the state of Alaska and the field of archaeology by providing information about how gender, class, ethnicity and transience played out during the gold rush.

The remaining sections are divided into the site-type categories proposed in Mills' model of gold rush archaeological sites (Part I, Chapter 3). Part II starts with three chapters on what the model identifies as transfer and supply points, Skagway and Dyea. The main purpose of these types of sites is to move people and supplies through the network. Thornton begins by uncovering the story of Tlingit gold rush participation at Chilkoot Pass. When the stampedeers arrived, the Tlingit were one of the wealthiest hunting and gathering societies in the world. They controlled a network of trails monopolizing trade with Natives in the interior. The Tlingit effort to maintain control of their trails resulted in the Packer War of 1888, during which a Tlingit chief was killed and control of the trails lost. Thornton also tells the story of Skookum Jim, the Native co-discoverer of gold in the Klondike, who straddles two worlds and is admired in each for different reasons. In the white-man world, he is appreciated for playing by their rules, wearing their clothes and living in their kind of house. In the Native world, he is appreciated for his traditional commitments to his family.

Cooper and Spude compare household collections in Skagway. Their findings include a priest who supported

Prohibition yet drank in secret; an interracial household that attempted to alleviate the stress of trying to integrate by consuming unusual amounts of “medicine”; a surprise military habitation revealed through multiple regression analysis, which instigated historical research confirming the archaeological evidence and demonstrated that the African American soldiers living there stole gunpowder from the military. The evidence from these assemblages points to people acting in accordance with their assigned gender and class roles. Huelsbeck uses a consumer-behavior approach to analyze eleven faunal assemblages from Skagway. He uses the type and amount of meat represented by the bones, price categories, and cooking methods to demonstrate that wealth and class played out as expected, at least in relation to beef consumption, and that people probably responded to price fluctuations by consuming more or less mutton.

In contrast to the discussion of coastal sites in Part II, Part III discusses interior transfer and supply links in the network. Griffin and Gurcke cover the thirty-year international effort to document the blanket of artifacts along the Chilkoot trail by archaeologists from Parks Canada and the U.S. National Park Service. They lament the paucity of prehistoric sites found in spite of the known history of Native use. Both agencies are trying to address the difficulties related to having two countries place their borders in the middle of a Tlingit trail that is an essential part of Native identity. “Canyon City,” by Hammer, is an analysis of a company town and how it controlled the resident employees’ lives whether on the clock or off. The layout of the town was highly structured, even to the organization of the wall tents, unlike other gold rush sites. The company maintained a monopoly over all available resources, causing the employees to be totally dependent on the company for food and shelter.

Part IV focuses on settlements that also serve as transfer and supply points but in addition provide essential services, such as shopping, medical, legal and recreational, to adjacent mining districts, identified in the model as Central and Secondary Distribution Settlements. C. Spude, Weaver, and Kardatzke look at five saloons and demonstrate how class and wealth are illustrated in the archaeological assemblages. Brand discusses how imported food was essential to the transient population living in tents on the hillsides of Dawson City because “there were insufficient natural resources in the Yukon to sustain a population the size of Dawson City during the boom years” (p. 215). Mills uses the example of Coldfoot

to demonstrate how one community changes through time and cycles through different site types of his model. Smith, Mills, and C. Spude analyze the small settlement of Tofty, significant because it was the first excavation of its model site type in either Alaska or Canada. The authors used Spude’s multiple linear regression analysis and found a midden composed entirely of liquor bottles and a cobbler’s home/workshop illustrating social and economic interconnectedness at this remote location.

The last section concentrates on actual mining sites. Saleeby analyzes over one hundred placer sites documented in a decade-long survey. No matter the type of dwelling recorded, whether a tent frame, cabin, or bunkhouse, her research found an amazing consistency in the types of artifacts at each site, illustrating the miners’ dependence on a recently industrialized economy with limited choices available. King’s contribution demonstrates that Alaska Natives, as well as whites, participated in the gold rush. He focuses on the Ahtna Athabaskans mining at Valdez Creek. Initially starting out as laborers for other miners, they acquired the necessary mining skills and eventually began leasing claims to mine themselves.

Higgs and Sattler illustrate how the differences between a prospector and a miner play out in the archaeological record at Fish Creek, an Extraction Camp site type near Fairbanks. The first site, a small roofless log structure containing rustic, hand-made furniture, is interpreted to be a prospector’s tent frame cabin that was only occupied for a season or less, during which time the occupant appears to have chewed more tobacco than food. The second site had a known occupant who lived there for possibly two decades. He constructed a slightly larger, more substantial cabin with additional features such as a privy, cold cellar, windows, and a porch. He participated in a wider variety of activities, from mining to baking. What the authors point out is that whether temporary or permanent, both cabin occupants relied on the industrialized food system for sustenance.

The authors succeed in their goal of pushing what is known about the gold rush out of the gray literature and into the mainstream. The book is widely available and accessible for someone without an archaeological background who is interested in the topic, although the authors could have expounded a little more on field-specific terminology without compromising scientific integrity. Aside from some redundancy regarding the model description, minor errors and some odd chapter placement, this book is overall an important contribution to the gold

rush literature. It will be a useful cornerstone for current and future historical archaeologists.

Like most characters who are mythologized, crusty sourdoughs did exist, but they were likely the exception rather than the rule. After reading *Eldorado!*, the image of the gold rush miner morphs into someone younger, better educated, and a bit wealthier, who had a fleeting presence in the state, simultaneously dependent on and contributing to a vast economic web.

Boreal Imagery



Dale Slaughter
906 W. 56th Avenue
Anchorage, AK 99518
907-562-1907 (h)
907-830-9370
archdles@ak.net

Artifact scanning/photography

High resolution film
and document scans

High quality prints from negatives and digital files

Photograph restoration

Map and profile
drawing

