

A zooarchaeological study of *Rangifer tarandus*  
(Linnaeus, 1758) from the Croxton site  
in Brooks Range, Alaska,  
and implications for utility analysis

Martina L. STEFFEN



DIRECTEUR DE LA PUBLICATION : Bruno David,  
Président du Muséum national d'Histoire naturelle

RÉDACTRICE EN CHEF / EDITOR-IN-CHIEF: Joséphine Lesur

RÉDACTRICE / EDITOR: Christine Lefèvre

RESPONSABLE DES ACTUALITÉS SCIENTIFIQUES / RESPONSIBLE FOR SCIENTIFIC NEWS: Rémi Berthon

ASSISTANTE DE RÉDACTION / ASSISTANT EDITOR: Emmanuelle Rocklin ([anthropo@mnhn.fr](mailto:anthropo@mnhn.fr))

MISE EN PAGE / PAGE LAYOUT: Emmanuelle Rocklin, Inist-CNRS

COMITÉ SCIENTIFIQUE / SCIENTIFIC BOARD:

Cornelia Becker (Freie Universität Berlin, Berlin, Allemagne)  
Liliane Bodson (Université de Liège, Liège, Belgique)  
Louis Chaix (Muséum d'Histoire naturelle, Genève, Suisse)  
Jean-Pierre Digard (CNRS, Ivry-sur-Seine, France)  
Allowen Evin (Muséum national d'Histoire naturelle, Paris, France)  
Bernard Faye (Cirad, Montpellier, France)  
Carole Ferret (Laboratoire d'Anthropologie Sociale, Paris, France)  
Giacomo Giacobini (Università di Torino, Turin, Italie)  
Véronique Laroulandie (CNRS, Université de Bordeaux 1, France)  
Marco Masseti (University of Florence, Italy)  
Georges Métailié (Muséum national d'Histoire naturelle, Paris, France)  
Diego Moreno (Università di Genova, Gènes, Italie)  
François Moutou (Boulogne-Billancourt, France)  
Marcel Otte (Université de Liège, Liège, Belgique)  
Joris Peters (Universität München, Munich, Allemagne)  
François Poplin (Muséum national d'Histoire naturelle, Paris, France)  
Jean Trinquier (École Normale Supérieure, Paris, France)  
Baudouin Van Den Abeele (Université Catholique de Louvain, Louvain, Belgique)  
Christophe Vendries (Université de Rennes 2, Rennes, France)  
Noëlie Vialles (CNRS, Collège de France, Paris, France)  
Denis Vialou (Muséum national d'Histoire naturelle, Paris, France)  
Jean-Denis Vigne (Muséum national d'Histoire naturelle, Paris, France)  
Arnaud Zucker (Université de Nice, Nice, France)

COUVERTURE / COVER:

*Rangifer tarandus* (Linnaeus, 1758). Photo © Yay Microagefotostock.

*Anthropozoologica* est indexé dans / *Anthropozoologica is indexed in:*

- Social Sciences Citation Index
- Arts & Humanities Citation Index
- Current Contents - Social & Behavioral Sciences
- Current Contents - Arts & Humanities
- Zoological Record
- BIOSIS Previews
- Initial list de l'European Science Foundation (ESF)
- Norwegian Social Science Data Services (NSD)
- Research Bible

*Anthropozoologica* est distribué en version électronique par / *Anthropozoologica is distributed electronically by:*

- BioOne® (<http://www.bioone.org>)

*Anthropozoologica* est une revue en flux continu publiée par les Publications scientifiques du Muséum, Paris, avec le soutien du CNRS.

*Anthropozoologica* is a fast track journal published by the Museum Science Press, Paris, with the support of the CNRS.

Les Publications scientifiques du Muséum publient aussi / The Museum Science Press also publish:

*Adansonia*, *Zoosystema*, *Geodiversitas*, *European Journal of Taxonomy*, *Naturae*, Cryptogamie sous-sections *Algologie*, *Bryologie*, *Mycologie*.

Diffusion – Publications scientifiques Muséum national d'Histoire naturelle

CP 41 – 57 rue Cuvier F-75231 Paris cedex 05 (France)

Tél. : 33 (0)1 40 79 48 05 / Fax: 33 (0)1 40 79 38 40

[diff.pub@mnhn.fr](mailto:diff.pub@mnhn.fr) / <http://sciencepress.mnhn.fr>

© Publications scientifiques du Muséum national d'Histoire naturelle, Paris, 2019  
ISSN (imprimé / print) : 0761-3032 / ISSN (électronique / electronic) : 2107-0817

# A zooarchaeological study of *Rangifer tarandus* (Linnaeus, 1758) from the Croxton site in Brooks Range, Alaska, and implications for utility analysis

**Martina L. STEFFEN**

University of Arizona, School of Anthropology,  
Emil W. Haury Anthropology Building, 1009 E South Campus Dr., Tucson AZ, 85721 (United States)  
[martinasemail@gmail.com](mailto:martinasemail@gmail.com)

Submitted on 25 April 2018 | Accepted on 27 August 2018 | Published on 22 March 2019

Steffen M. L. 2019. — A zooarchaeological study of *Rangifer tarandus* (Linnaeus, 1758) from the Croxton site in Brooks Range, Alaska, and implications for utility analysis. *Anthropozoologica* 54 (4): 29-43. <https://doi.org/10.5252/anthropozoologica2019v54a4>. <http://anthropozoologica.com/54/4>

## ABSTRACT

This paper focuses on the identification and interpretation of a sample of vertebrate faunal remains from the Croxton archaeological site, located at Tukuto Lake, on the north slope of the Brooks Mountain Range, Alaska, in which caribou (*Rangifer tarandus* (Linnaeus, 1758)) dominate. Bone modifications are assessed to inform selection and processing, and skeletal part frequencies are analyzed with utility indices developed for this species among the Nunamiut at Anaktuvuk Pass. Results confirm the accumulation of faunal remains resulted primarily from human subsistence activities in the middle to late Holocene that included nutritional uses for meat, marrow and grease as well as technology manufacturing. Statistical utility analyses point to a deposit of marrow and grease processing debris at an activity area and support these as enduring subsistence practices in this region. A previous study on a larger faunal sample from the site also indicated a range of economic uses of caribou but did not find significant results with utility indices. To explain this difference it is suggested that the faunal aggregates chosen for analysis in this and the previous study have influenced statistical outcomes. The results of this study hold implications for utility analysis as well as for interpretations of caribou use at archaeological sites in arctic, sub-arctic, and alpine tundra areas of the Northern Hemisphere where this species has been abundant.

## KEY WORDS

Archaeology,  
utility indices,  
zooarchaeology,  
taphonomy,  
*Rangifer tarandus*,  
North America,  
Alaska.

## RÉSUMÉ

*Une étude zooarchéologique des Rangifer tarandus (Linnaeus, 1758) du site de Croxton dans la chaîne Brooks, Alaska, et implications pour l'analyse de l'utilité.*

Cet article porte sur l'identification et l'interprétation d'un nouvel échantillon de restes de vertébrés provenant du site archéologique de Croxton, localisé près du lac Tukuto, sur le versant nord de la chaîne de montagnes Brooks en Alaska, dans lequel dominent les caribous (*Rangifer tarandus* (Linnaeus, 1758)). Les modifications osseuses sont recherchées pour éclairer la sélection et le traitement de ces proies. Les fréquences des parties squelettiques sont analysées à l'aide d'indices d'utilité développés pour cette espèce chez les Nunamiut d'Anaktuvuk Pass. Les résultats confirment que l'accumulation des restes de faune résulte principalement d'activités de subsistance humaine, incluant l'utilisation nutritionnelle de la viande, la moelle et la graisse, ainsi que l'utilisation technique de matière première. Les analyses statistiques révèlent l'utilisation de moelle osseuse et de graisse dans une zone d'activité à l'intérieur du site et attestent de pratiques de subsistance durables dans la région considérée.

**MOTS CLÉS**  
 Archéologie,  
 indices d'utilité nutritive,  
 zooarchéologie,  
 taphonomie,  
*Rangifer tarandus*,  
 Amérique du Nord,  
 Alaska.

Une précédente étude réalisée sur un plus grand échantillon de la faune de ce site a également montré une variété d'utilisations économiques du caribou, mais aucun résultat significatif concernant les indices d'utilité. Pour expliquer cette différence, il est suggéré que les agrégats osseux choisis pour analyse dans cette étude et dans la précédente ont probablement influencé les résultats statistiques. Les données obtenues dans cette étude ont des répercussions sur les analyses ainsi que sur l'interprétation de l'utilisation du caribou dans les sites archéologiques des régions arctiques, subarctiques et de la toundra alpine de l'hémisphère Nord, où cette espèce est abondante.

## INTRODUCTION

As a circumpolar species, caribou<sup>1</sup> (*Rangifer tarandus* (Linnaeus, 1758)) have a long history as a human subsistence resource in North America and Eurasia, where hunting and the utilization of these animals have been studied from numerous perspectives (Banfield 1951; Bouchud 1966; Burch 1972; Binford 1978; Spiess 1979; Meltzer 1988; Gordon 1990; Rignaud & Simek 1990; Jackson & Thacker 1997; Bridault *et al.* 2000; Grayson *et al.* 2001; Weinstock 2002; Enloe 2003; Mellars 2004; Gotfredsen 2010; Hoffeecker *et al.* 2010; Kuntz & Costamagno 2011; Pasda & Odgaard 2011; Friesen & Stewart 2013; Magniez *et al.* 2013; O'Shea *et al.* 2014). Lewis Binford's influential ethnoarchaeological study of subsistence practices amongst the Nunamiut at Anaktuvuk Pass, Alaska, observed procurement and processing activities that included caribou exploitation for meat and within-bone nutrients as marrow and grease (Binford 1978). He studied how marrow-rich bones were selected and ends broken off or bone shafts broken open to access the marrow inside after soft tissue was removed. Sometimes long bone epiphyses were stockpiled for subsequent grease rendering. Grease extraction was a more labour and time intensive process in which this resource was liberated from the porous matrix of trabecular bone by placing fragments in containers with heated water; grease was then skimmed off the water surface (Leaechman 1951; Yellen 1977; Binford 1978; Church & Lyman 2003).

Binford's study found that people often made reasonable decisions when processing for subsistence uses and tended to target portions that contained high value for the desired food source. Anatomical parts yield different quantities of nutrients types, with highest meat utility typical of fleshier parts of the animal such as those around the upper hind leg, high marrow value typical of metapodials, and grease in high concentrations in trabecular bone of limb ends. From these observations, utility indices were developed of the relative food value for anatomical portions as standards with which faunal analysts can evaluate caribou use based on skeletal part frequencies. Where animals were routinely portioned in keeping with high values for general utility or specific target nutrients as grease and marrow, and these behaviours are preserved in the archaeological context, statistical comparisons with utility indices can return correlations with which to infer subsistence uses in the past.

Foragers decisions about hunting and butchery can be reflected in the anatomical portions of prey animals at a site as a whole and can also influence within-site spatial patterning of faunal remains. Ethnoarchaeological studies of living foragers suggest that foraging decisions may be motivated by many factors including prey size and the distance between the capture location and a base camp (Binford 1978; Bunn *et al.* 1988; O'Connell *et al.* 1988), so that the portions of prey animals at a site can reflect local availability and the degree of food security. For instance, where food security was high and ungulates were routinely caught at or nearby an occupation site and processed, entire animals may be represented in the archaeological sample. If local resources were depleted and game animals were sought further afield, foragers are likely to butcher the animals at the kill site and select high-value portions for transport back to a living site, thus biasing kill and living site assemblages in terms of the relative value of anatomical portions (Stiner 1991, 2005; Broughton 1999). Butchery and processing activities can also result in spatial patterning of faunal remains within a site (Binford 1983; O'Connell 1987; Enloe 2003). For example, ungulate vertebrae and phalanges that are associated with lower nutritional values may be removed from the animal first and at some distance from hearths where higher value anatomical portions are processed for food and found in higher relative abundance (Enloe 2003). In Alaska specifically the ways in which marrow and grease processing were conducted by the Nunumuit suggest that bone deposits linked with these activities can have a spatial element with identifiable areas where marrow cracking took place and shaft splinters and boiled bone elements were discarded (Binford 1983). Skeletal element frequencies can, therefore, be informative on site-wide and within-site scales of analysis.

Zooarchaeological studies are typically interpreted alongside taphonomic evidence. Analyses often include observations on fragmentation, burnt bones, cut and bite mark patterning and bone density studies that can help to sort out all of the factors involved in bone survivorship (Lyman 1985, 1994; Fernández-Jalvo & Andrews 2016). The approach combining utility analysis and taphonomic evidence has been used widely by analysts to assess subsistence practices and the efficiency with which people regularly utilized anatomical portions of caribou or other animals for which utility indices have been developed (Blumenshine & Caro 1986; Metcalfe & Jones 1988; O'Connell & Marshall 1989; Lyman *et al.* 1992; Savelle & Friesen 1996; Brink 1997; Outram & Peter 1997).

1. The common name for *Rangifer tarandus* in North America is caribou. This is synonymous with reindeer.

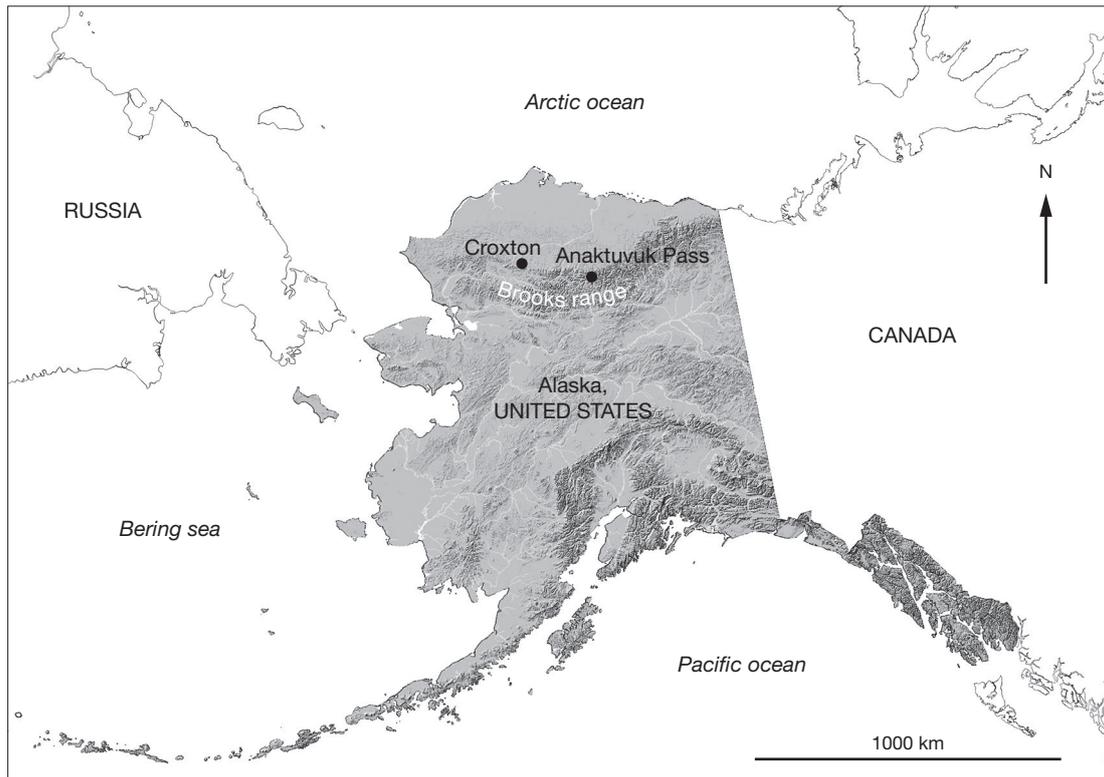


FIG. 1. — Map showing the locations of the Croxton archaeological site and the modern village of Anaktuvuk Pass along the north slope of the Brooks Mountain Range, Alaska, United States.

The present study examines a sample of faunal remains from the Croxton archaeological site in north-central Alaska (Fig. 1), a caribou hunting and processing location spanning approximately 2000 years during the late Holocene. Prime objectives are to define subsistence at the site through identification of faunal remains, calculation of primary and secondary measures of faunal abundance, and evaluation of anatomical part frequencies to assess the utilization of caribou. These analyses are provided in tandem with taphonomic observations to identify the main human and non-human factors that have affected skeletal element frequencies and include the potential role of bone density in survivorship. The analyzed faunal sample was excavated from one area of the site and results will, therefore, provide a within-site perspective on subsistence activities at Croxton to augment results obtained in a previous faunal study on a larger site-wide sample (Gerlach 1989). The present study posits that prehistoric uses of caribou are accessible through analyses of the faunal sample and are likely to have included subsistence practices comparable to those observed by Binford at Anaktuvuk Pass, the modern village in a similar environment fewer than 500 kilometers to the east.

#### THE CROXTON SITE

The Croxton site is located on the north foothills of the Brooks Mountain Range, along the eastern shore of Tukuto Lake, and consists of two areas, K and J, on a lower and upper terrace, respectively. Excavations at this approximately 5600 square meter site in the 1980s were extensive and resulted in the collection of numerous

faunal remains, artifacts and features across area J. These excavations were followed in AD 2000 by a small amount of additional subsurface testing in area J of three adjacent excavation units to gather samples from an exposed sediment profile for chronometric dating (Gerlach 1989; Reuther & Gerlach 2005). Both projects used stratigraphy to define excavation levels. The faunal remains recovered from the site in AD 2000 are reported here.

Two cultural units, an Arctic Small Tool Tradition and an Ipiutak component, have been identified at the site. The Arctic Small Tool Tradition characterized at this locality as Denbigh, dates from as early as 5500 years ago in northern Alaska (Anderson 1984; Dumond 1984; Nuttall 2005). The Denbigh phase is notable for finely made foliate projectile points and is divided into proto and classic phases. Microblades and microblade cores start as oval-platformed cuboid forms with more acute-angle-platformed cores in classic Denbigh. Tanged end scrapers in early Denbigh give way to a higher abundance of untanged and triangular end scrapers in the classic phase. Small bipointed end and side blades as insets into antler arrow and spear heads are common throughout, as are chipped-stone semi-lunar and unifacial knives, flaked burins and notched stone net sinkers. Ground adz blades and burins are present in classic Denbigh. The Ipiutak tradition dates from approximately 2000-700 years ago (Anderson 1984; Gerlach & Mason 1992). This culture is notable for elaborate burial goods that include ivory carvings as well as for the early use of iron in the Arctic. A wide variety of tools were manufactured, including antler arrow and harpoon heads, bifaces, unifacial flaked knives, discoid scrapers, lunate bifacial knives and ground stone burin-like tools.

At the Croxton site, radiocarbon age estimates on cultural deposits span from  $3760 \pm 135$  BP (Beta 134995,  $4520-3726^2$  cal BP; Reuther & Gerlach 2005) to at least  $1075 \pm 120$  BP (GX 8635, 1265-764 cal BP), with Denbigh deposits dating to  $1670 \pm 160$  BP (GX 8636, 1941-1291 cal BP; Gerlach 1989), possibly indicating a late terminal date for the cultural component at this site. Excavations in the 1980s found underlying Denbigh material was limited and horizontally discontinuous, whereas the Ipiutak component comprised most of the excavated cultural deposits. Although analysis of artifacts and a stratigraphic concordance between the two excavations are in progress by the proponents of this site, preliminary results from the AD 2000 excavation indicate the transition between Denbigh and Ipiutak components in level 5 (Ruther pers. comm.), denoting that both cultural components are included in the present study.

Archaeological materials at Croxton consist primarily of debris associated with hunting and processing caribou. Study of caribou bones recovered in the 1980s consisted of 16766 identified specimens from numerous excavations units that comprised the Ipiutak cultural component (Gerlach 1989). Assessment of the wear stages of lower molars and bone fusion showed caribou spanned several phases of maturity (Gerlach 1989: 328, table 43) and indicated seasonal hunting in which caribou were likely to have been taken during their northward migration in spring, the southward migration in autumn, and throughout summer (Gerlach & Hall 1988). Although caribou remains spanned several age groups, prime-aged adult animals were most abundant in the assemblage. This pattern is consistent with a widely recognized tendency in human hunting for selection of prime adult ungulates that offer high food value for effort (Stiner 1990, 2005). Adult biased mortality also supports that hunters are likely to have used ambush techniques to target individual animals from herds in and around Tukuto Lake. People were situated at Croxton to intersect annual caribou migration so that many animals could be caught nearby. Hunting with spears from boats as caribou cross waterbodies and then hauling animals onto the beach for processing is an ethnohistorically documented practice that has been associated with bone accumulations on lake shorelines in northern interior Alaska (Ingstad 1954: 49). This is likely to have been one of the methods employed at Croxton and may have resulted in whole animals often having been present at the site.

## MATERIAL & METHODS

Specimens were analyzed with conventional zooarchaeological methods. (Binford 1978; Grayson 1984; Reitz & Wing 1999; Stiner 2002). Identifications were made based on visual examination and physical comparisons with known faunal specimens in the Paleolithic Laboratory at the University of Arizona and the Stanley J. Olsen Zooarchaeology Laboratory at the Arizona State Museum in Tucson, USA. Taphonomic characteristics of

the assemblage assessed sources of bone survivorship and destruction as modifications to each bone specimen and included occurrences of carnivore bite marks, cut, hack and percussion marks; bone surface staining, weathering as cracking and exfoliation, dissolution of bone surfaces due to corrosion or digestion, and burnt bones. Taphonomic attributes can often be assigned to an agent. This analysis relied on Fernández-Jalvo & Andrews (2016) and Behrensmeyer (1978). Additionally, bone fragment lengths were measured per bone type and taxonomic group to assess the degree of fragmentation. All results were compared across excavation levels 4 that contains Ipiutak and 5 that contains a transition between Denbigh and Ipiutak to identify variability that could bias skeletal part counts.

Primary and secondary measures of faunal abundance were calculated. Numbers of identified specimens (NISP) were counted for each taxonomic group. The minimum number of individuals (MNI) was calculated per level for each taxon based on paired elements, size, and ontogeny. The minimum number of elements (MNE) was also calculated. MNE assesses how many of each bone element are present in an assemblage and provides a foundation for additional numerical analysis. It is typically calculated in one of two or three ways. The overlap approach in which specimen comparisons are made based on bone features and zones to determine minimum numbers per element is perhaps the most common. The fraction summation method estimates the portion of specific skeletal element zones present in a fragment, then all fractions of similar skeletal element zones per taxon are summed to estimate the abundance of the element (Klein & Cruz-Uribe 1984). A third method of estimating MNE uses a GIS pixel image-analysis for counting non-overlapping fragments (Marean *et al.* 2001). In the present study, MNE was calculated with the overlap approach. These values were then used to estimate the minimum animal units (MAU) by dividing the value for each bone type by the expected number of elements in an original skeleton. MAU values were then transformed into a percentage by dividing the value for each skeletal element by the highest MAU in the analytical unit. This %MAU value was compared statistically with various utility indices such that significant positive correlations may indicate human selection of carcass portions toward interpreting human subsistence.

Utility indices provide a testable expectation of how people targeted prey body parts in terms of relative food value. Four of these indices for caribou were employed in the present study:

- the meat utility index is calculated based on the weight of muscle and fat tissue of each anatomical part;
- the marrow index returns the percent fatty acids in marrow multiplied by marrow-cavity volume;
- the grease index reflects the percent fatty acids in cancellous bone multiplied by the volume of cancellous bone;
- the modified general utility index (MGUI) is calculated based on the weight of muscle and fat tissue, marrow, and grease in a given anatomical part and accounts for the regular inclusion of low-value bone elements that are attached to those of high-value in caribou anatomy.

To show the compliment of prey body parts present in the archaeological sample as another way to detect human selection biases in butchery and transport, the cari-

2. Radiocarbon age estimates have been calibrated to calendar age ranges with the IntCal13 calibration curve (Reimer *et al.* 2013) in OxCal, Version 4.3 (Bronk Ramsey 2009).

TABLE 1. — Croxton site species list.

Taxa	Level 1		Level 2		Level 3		Level 4		Level 5		All levels	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
Osteichthyes	–	–	–	–	–	–	21	1.75	1	0.25	22	1.32
Aves, medium-large	–	–	–	–	–	–	34	2.84	2	0.50	36	2.15
<i>Gavia</i> sp. (Forster, 1788)	–	–	–	–	–	–	3	0.25	–	–	3	0.18
Mammalia, indeterminate	1	100	9	34.62	10	22.72	280	23.37	87	21.54	387	23.13
Mammalia, smal-medium	–	–	–	–	–	–	4	0.33	2	0.50	6	0.36
Mammalia, large	–	–	–	–	6	13.64	87	7.26	23	5.69	116	6.93
Carnivora, small	–	–	–	–	–	–	1	0.08	–	–	1	0.06
Canidae	–	–	–	–	–	–	1	0.08	–	–	1	0.06
<i>Canis</i> sp. (Linnaeus, 1758)	–	–	–	–	–	–	1	0.08	–	–	1	0.06
<i>Castor canadensis</i> (Kuhl, 1820)	–	–	–	–	–	–	2	0.17	–	–	2	0.12
Cricetidae	–	–	–	–	–	–	1	0.08	–	–	1	0.06
<i>Lemmus</i> sp. (Link, 1795)	–	–	–	–	–	–	2	0.17	–	–	2	0.12
<i>Microtus</i> sp. (Schränk, 1798)	–	–	1	3.85	–	–	–	–	–	–	1	0.06
<i>Microtus oeconomus</i> (Pallas, 1776)	–	–	2	7.69	–	–	–	–	–	–	2	0.12
Artiodactyla, medium	–	–	2	7.69	7	15.91	312	26.04	108	26.73	429	25.64
Cervidae, medium	–	–	–	–	–	–	34	2.84	6	1.49	40	2.40
Cervidae, large	–	–	–	–	–	–	1	0.08	–	–	1	0.06
<i>Rangifer tarandus</i> (Linnaeus, 1758)	–	–	8	30.77	21	47.72	365	30.47	175	43.32	569	34.01
Vertebrata, indeterminate	–	–	4	15.38	–	–	49	4.10	–	–	53	3.17
Total	1	100	26	100	44	100	1198	100	404	100	1673	100

bou anatomy was compressed into nine regions following Stiner (1991): antler, head, neck, axial skeleton, upper front limb, lower front limb, upper hind limb, lower hind limb and feet. The sample of caribou remains in this study was excavated from one area of the archaeological site so that biases in skeletal anatomy that differ from anatomical patterning in the site overall may indicate internal spatial patterning that relates to the selection and deposition of caribou portions.

Caribou MNE values were derived from data in Gerlach (1989) to make them comparable with how MNEs were calculated in the present study. The MNE value for antler was derived from Table 17 (Gerlach 1989: 293) and comprised whole antlers plus main beam elements; cranial portion MNE was based on auditory bullae. The MNE for mandibles was derived from complete and ascending ramus elements in Table 18 (Gerlach 1989: 294). Axis vertebrae MNE was calculated based on values in Table 20 (Gerlach 1989: 295) as complete, neural arch, plus arch and spine elements. Cervical vertebra MNE was based on Table 17 complete elements plus neural arch, body and arch, and arch and spine. Thoracic vertebrae MNE was calculated as complete vertebrae, spines, plus arch and spine elements; and lumbar vertebrae MNE was calculated as complete, neural arch, plus arch and spine. Rib MNE was calculated from Table 22 (Gerlach 1989: 296) as complete elements and articulations. Innominate MNE was calculated from Table 21 (Gerlach 1989: 296) as complete and ilium elements. Scapula MNE was based on complete elements plus blades (Gerlach 1989: 297, table 23). MNEs for whole long bones were derived from complete elements plus the highest value from shaft fragments, distal or proximal ends; and MNEs for distal and proximal long bone ends included complete specimens (Gerlach 1989: 308, table 30). Complete and fragmented phalanges (Gerlach 1989: 300, table 29) were

equivalent in the 1989 sample and these may be overestimated compared with MNEs in the AD 2000 sample that considered nonoverlapping portions of elements.

The degree to which skeletal element frequencies may be biased by density mediated attrition was assessed by comparison with computed tomography (CT) measures as bone mineral density indices. Specifically, *Rangifer tarandus* CT values (Lam *et al.* 1999, BMD type 1) were used in these assessments. Statistical comparisons between the various indices and occurrences skeletal element frequencies in the archaeological faunal samples were calculated with Spearman's Rho.

## RESULTS

### TAXONOMIC ABUNDANCE

The Croxton faunal sample consists of 1673 bone specimens and includes small and large terrestrial mammals, birds, and fish (Tables 1, 2). Caribou comprise 98% of the genus and species level identifications and 34% of the total faunal sample. Medium artiodactyl and medium cervid bone fragments that likely consist primarily of caribou comprise 26% and 2.4% of the total bone count. Indeterminate mammal specimens comprise 23% of the assemblage and consist of small fragments, as do large mammal elements at 7% of the total. One specimen of large elk or moose-sized cervid is also present. Approximately 2% of the assemblage are medium or large bird bone fragments, with *Gavia* sp. (Forster, 1788) as the only genus-level avian identification. Specimens of small bony fishes consisting mainly rib and spine fragments comprise 1.3% of the total. Small carnivore, Canidae, and *Canis* sp. (Linnaeus, 1758) are present in level 4. Rodents in level 4 include small numbers of Cricetidae, *Lemmus* sp. Link, 1795 and *Castor canadensis* (Kuhl, 1820). *Microtus oeconomus* (Pallas, 1776), following Hall (1981), are present in level 3.

TABLE 2. — Croxton site minimum numbers of individuals (MNI).

Taxa	Level 1	Level 2	Level 3	Level 4	Level 5	Total
Osteichthyes	–	–	–	1	1	2
Aves, medium – large	–	–	–	1	1	2
<i>Gavia</i> sp. (Forster, 1788)	–	–	–	1	–	1
Mammalia, indeterminate	1	–	–	–	–	1
Mammalia, small – medium	–	–	–	–	1	1
Canidae	–	–	–	1	–	1
<i>Canis</i> sp. (Linnaeus, 1758)	–	–	–	1	–	1
<i>Castor canadensis</i> (Kuhl, 1820)	–	–	–	1	–	1
Cricetidae	–	–	–	1	–	1
<i>Microtus oeconomus</i> (Pallas, 1776)	–	1	–	–	–	1
<i>Lemmus</i> sp. (Link, 1795)	–	–	–	1	–	1
Cervidae, large	–	–	–	1	–	1
<i>Rangifer tarandus</i> (Linnaeus, 1758)	–	1	2	6	8	17
Total MNI	1	2	2	15	11	31

On the basis of humeri, caribou comprise a minimum of 17 individuals and are by far the most abundant prey animal present in the assemblage.

**BONE MODIFICATIONS**

Bone modifications were assessed (Table 3). Taphonomic evaluation of the bone assemblage indicates human and non-human sources of bone modification.

*Modifications by humans*

Ninety-seven cut marks were recorded on bone specimens, 19 of these cuts on bird specimens are longitudinal to section long bones into slivers, probably for use as needles or perforators. Cut marks (Table 4) on artiodactyl humeri, femora, thoracic and lumbar vertebrae and ribs indicate damage associated with carcass partitioning and meat removal (Binford 1978, 1981). Bone fragments of indeterminate mammals also show cut marks. Less meaty cranial and phalange fragments with cuts may be indicative of skinning, and hack marks on antler fragments are likely to have been produced during removal, probably for raw material in tool manufacture (Fig. 2).

Modifications include observation of 140 percussion cones on bone specimens that are consistently on the insides of long bone fragments in caribou-sized categories (Table 5), several of which are on opposing sides of the same shaft indicative of the use of hammer and anvil. Impact cones appear on caribou humeri and tibias, bones associated with relatively high meat utility that also contain marrow, as well as on metapodial shaft fragments that have higher marrow than meat value. Many specimens are spiral fractured, signaling that bones were fragmented before significant weathering occurred

(Behrensmeier 1978). Several first and second phalanges of caribou were opened near the proximal end, presumably to remove medullary marrow.

Numerous specimens show clear evidence of having been altered by fire including 148 small (< 16 mm long) calcined fragments, which suggests animal bones may have been part of cooking processes as bone discarded into and nearby fires in association with nutrient extraction activities (discussion in Church & Lyman 2003). Grease-rich limb bone ends were not burned more often than other bone portions and so do not appear to have been used as a source of fuel (Théry-Parisot 2002; Villa *et al.* 2002).

Bone fragment lengths were measured and compared among similarly sized mammals (Table 6). Results indicate no statistically significant difference in fragment size across levels.

*Non-human modifications*

Tooth marks noted on 49 (3%) specimens were typically small (*c.* 5 mm diameter) and circular isolated punctures through trabecular bone that are consistent with damage by small- to medium-sized carnivores, possibly canids. Carnivore bite marks are likely to have been those of domesticated dogs, though could also have been from wild animals such as foxes or wolves that range in northern Alaska (Wilson & Reeder 2005).

Alteration of bone surfaces is common in the identified assemblage. The dark brown staining on most specimens is indicative of discoloration during burial in humic soil. Exfoliation and cracking of surface bone is also common in the assemblage. This can result from natural weathering during aerial exposure before burial and can also occur with dissolution in moist burial environments with acidic humic content, due to chemical alteration during extended exposure to acids from carnivore gnawing or digestion (Fernández-Jalvo & Andrews 2016), and in bones boiled for grease rendering that may be exceptionally susceptible surface degradation due to a weakened bone structure (Gifford-Gonzalez 1993). Separating the sources of bone surface modifications can, therefore, be complicated. To identify the main taphonomic agents in the Croxton bone sample, frequencies and percentages of bones showing types of attributes are informative. With only 3% of bones showing carnivore bite marks compared to aerial exposure weathering as surface cracking or exfoliation identified on 419 (25%) specimens, and moisture corrosion of bone surfaces recorded on 890 (53%) specimens, it seems likely that carnivores contributed a relatively minor portion of the overall extent of bone damage. Furthermore, characteristics of carnivore digested bone including localized surface polish, pitting, or penetration through the bone surface in a torn appearance and bone removal that conforms to the structure of bone canals, osteons and lamellae are not typical of surface damage at Croxton. Many bones with aerial exposure weathering fall into Stage 1 or 2 (Behrensmeier 1978), showing a limited amount of surface cracking and some deeper cracks with exfoliation. Altered bone surfaces were most often ubiquitous mottled corrosion marks and surface flaking in patches, sometimes with root etching or curled-up edges characteristic of exposure to moisture. In sum, aerial weathering and then exposure to moisture in humic soil contributed

TABLE 3. — Modifications of bone specimens in level 4, level 5, and all levels at the Croxton site. Levels 1-3 contained low NISP and the few modifications from these levels are calculated with levels 4 and 5 in All levels. \* Seven elements of a lower hind leg were found articulated. Abbreviation: L., level.

Taxa	Cut			Cone			Hacked			Burned NISP			Burned <16 mm		
	L. 4	L. 5	All levels	L.4	L. 5	All levels	L. 4	L. 5	All levels	L. 4	L. 5	All levels	L. 4	L. 5	All levels
Aves, medium-large	19	–	19	–	–	–	–	–	–	2	1	3	–	–	–
Mammalia, indeterminate	3	–	3	8	1	9	–	–	–	23	18	41	66	10	81
Mammalia, small-medium	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–
Mammalia, large	9	2	11	5	3	8	–	–	–	21	3	24	–	–	–
<i>Canis</i> sp. (Linnaeus, 1758)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Castor canadensis</i> (Kuhl, 1820)	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–
Artiodactyla, medium	14	–	14	30	5	35	–	–	–	30	17	47	–	–	–
Cervidae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cervidae, medium	1	–	1	1	–	1	–	–	–	6	1	7	–	–	–
Cervidae, large	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Rangifer tarandus</i> (Linnaeus, 1758)	33	10	49	53	32	87	10	12	22	56	20	79	18	–	18
Vertebrata, indeterminate	–	–	–	–	–	–	–	–	–	–	–	–	45	–	49
<b>Total</b>	<b>79</b>	<b>12</b>	<b>97</b>	<b>97</b>	<b>41</b>	<b>140</b>	<b>10</b>	<b>12</b>	<b>22</b>	<b>140</b>	<b>60</b>	<b>203</b>	<b>129</b>	<b>10</b>	<b>148</b>

Taxa	Carnivore bite marks			Weathering			Dissolution			Articulation		
	L. 4	L. 5	All levels	L. 4	L. 5	All levels	L. 4	L. 5	All levels	L. 4	L. 5	All levels
Aves, medium-large	–	–	–	1	1	2	7	1	8	–	–	–
Mammalia, indeterminate	1	1	2	41	37	85	136	48	185	–	–	–
Mammalia, small-medium	–	–	–	–	2	2	2	2	4	–	–	–
Mammalia, large	2	3	5	11	10	23	28	13	47	–	–	–
<i>Canis</i> sp. (Linnaeus, 1758)	–	–	–	–	–	–	–	–	–	–	–	–
<i>Castor canadensis</i> (Kuhl, 1820)	–	–	–	–	–	–	–	–	–	–	–	–
Artiodactyla, medium	4	1	6	71	54	134	197	74	288	–	–	–
Cervidae	–	–	–	–	–	–	–	–	–	–	–	–
Cervidae, medium	6	1	7	6	6	12	18	6	24	–	–	–
Cervidae, large	–	–	–	1	–	1	–	–	–	–	–	–
<i>Rangifer tarandus</i> (Linnaeus, 1758)	16	12	29	70	68	160	194	117	334	7(1)*	–	7(1)*
Vertebrata, indeterminate	–	–	–	–	–	–	–	–	–	–	–	–
<b>Total</b>	<b>29</b>	<b>18</b>	<b>49</b>	<b>201</b>	<b>178</b>	<b>419</b>	<b>582</b>	<b>261</b>	<b>890</b>	<b>7(1)*</b>	<b>–</b>	<b>7(1)*</b>

TABLE 4. — Skeletal element distribution of cut marks in level 4 and level 5 at the Croxton site. In addition to those listed in this table, two cut marks are present on the shaft fragment of a caribou femur in level 3. Abbreviation: L., level.

Skeletal element	Aves, medium-large		Mammal, small-medium		Mammalia, indeterminate		Mammalia, large		Artiodactyla, medium		Cervidae, medium		<i>Rangifer tarandus</i> (Linnaeus, 1758)	
	L. 4	L. 5	L. 4	L. 5	L. 4	L. 5	L. 4	L. 5	L. 4	L. 5	L. 4	L. 5	L. 4	L. 5
Antler	–	–	–	–	–	–	–	–	–	–	–	–	28	8
Skull, temporal	–	–	–	–	–	–	–	–	7	–	–	–	–	–
Vertebra	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Cervical vertebra	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Thoracic vertebrae, transverse process	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Lumbar vertebrae, pre-zygapophyses	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Rib, near proximal epiphysis	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Rib, body fragment	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Humerus, proximal shaft	–	–	–	–	–	–	–	–	–	–	–	–	2	–
Femur, proximal shaft	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Long bone shaft fragment	19	–	–	–	–	–	6	–	5	–	–	–	–	–
First phalanx, proximal	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Second phalanx, proximal	–	–	–	–	–	–	–	–	–	–	–	–	1	2
Fragment	–	–	–	–	–	–	3	2	–	–	–	–	–	–
<b>Total</b>	<b>19</b>	<b>–</b>	<b>–</b>	<b>–</b>	<b>3</b>	<b>–</b>	<b>9</b>	<b>2</b>	<b>14</b>	<b>–</b>	<b>1</b>	<b>–</b>	<b>33</b>	<b>10</b>

significantly to occurrences of bone surface degradation in the archaeological specimens.

Overall, taphonomic analyses indicate that humans were primary agents of bone deposition and contributed to bone

modification in the faunal sample. The effects of fragmentation and other observable bone modifications are similar in levels 4 and 5 and likely have equivalent effects on the entire assemblage in terms of skeletal element attrition.

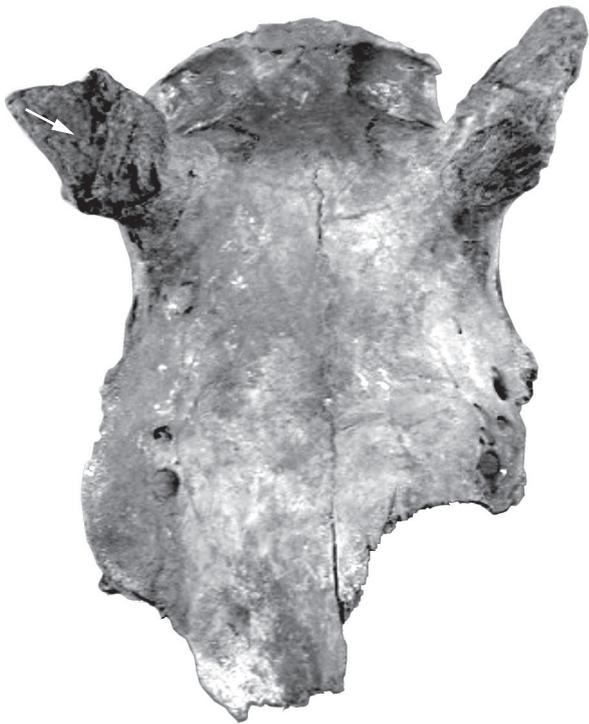


FIG. 2. — A caribou (*Rangifer tarandus* (Linnaeus, 1758)) partial cranium with antlers removed. The white arrow points toward linear hack marks. Scale bar: 10 cm.

#### SKELETAL PORTION FREQUENCIES & DENSITY MEDIATED ATTRITION OF CARIBOU BONES

Caribou anatomical regions for levels 4 and 5, the within-site samples, as well as the 1989 faunal sample show biases in anatomical portions as variation in bar heights (Fig. 3). Highest values in the 1989 sample are upper hind legs that have abundant nutritional value for meat and general utility and may indicate selection and transport of high-value body portions to the upper terrace at area J. Low relative abundance of foot, neck and axial elements in the 1989 sample could indicate early sectioning off of lower utility portions during butchery, though moderately high relative frequencies of head elements may seem difficult to reconcile with this. Mandibles are the most abundant element in the head category and could have been for access to marrow contained in the mandibular body, as most were broken open. Low relative abundance of antler in the 1989 sample may relate to season of occupation or other factors. Though the timing of annual antler shedding varies in caribou, males typically carry them through summer and shed after mating in late autumn, while barren females and juveniles shed antlers in early spring, and pregnant females in May or June, after giving birth. At Croxton, low relative abundance of antler could indicate hunting of female caribou in summer but is perhaps more likely to indicate removal of these elements from the site in technology or as raw materials, as antler tools are common in arctic prehistory. Consistent with this interpretation are hack marks on antler as well as a concentration of these elements noted during excavation by Gerlach (1989: 160, fig. 20) that evokes special treatment.

Similar to the 1989 sample, bar charts for levels 4 and 5 show low relative abundances of foot, neck and axial portions of the skeleton, and the upper hind leg is well-represented. Levels 4 and 5 also differ from the 1989 sample. Antler is in higher relative abundance in level 4 than in the other Croxton samples and may indicate a stockpile of these elements. Grease utility is highest in upper leg regions of the proximal humerus as well as in the distal femur and proximal tibia of the lower leg and these are the highest values in levels 4 and 5, as are portions related to marrow utility from the distal tibia through the carpals of lower legs. This pattern is expected if lower and upper limb bones were transported to this location within the site and is consistent with people targeting high-value regions for marrow and grease as well as meat in upper leg portions. It is interesting to note that one relatively complete lower hind leg that had marrow removed and included the distal tibia with impact cones and the metatarsal split on the long axis was excavated in the level 4 sample (Table 3, Articulation; Fig. 4). Although there are similarities in the 1989 and AD 2000 skeletal element distributions including emphasis on upper hind limbs, the AD 2000 samples show relatively more emphasis on lower limbs that have high marrow value and upper front limbs that have high grease value.

Neck and axial portions of the skeleton are consistently under represented across the Croxton samples and because fragile vertebrae and ribs contribute to these portions, the influence of bone density on attrition is a consideration. The CT density index for caribou was compared with relative frequencies of caribou-sized bone elements in levels 4 and 5 and the 1989 sample to assess the potential contribution of bone density mediated attrition on skeletal element survivorship. Despite the presence of destructive processes as evidenced by human-made bone damage, bone surface dissolution, exfoliation, and gnawing by carnivores, the structural density of skeletal elements does not appear to be a very strong predictor of bone survivorship in the analyzed faunal samples (Table 7), supporting that skeletal portion representation reflects human decisions about transport, processing and deposition of caribou.

#### ECONOMIC ANATOMY: %MAU AND THE MGUI

Utility indices for meat, marrow, grease and MGUI were compared with anatomical parts of caribou-sized bone elements (Table 7). Significant positive correlations with marrow and grease utility indices resulted in levels 4 and 5. Reanalysis of the 1989 sample with these indices gave significant positive correlations with the MGUI and points to selective transport of high-value portions to area J.

Each %MAU value was also charted with MGUI to examine proportional frequencies of elements and the types of subsistence strategies that may have been employed (Binford 1978; Lyman 1985, 1994; Faith & Gordon 2007). Based on the direction of the resulting curvilinear relationship this method can assist in distinguishing a bulk strategy in which body parts of high and moderate value are selected and lower value parts are abandoned, from a gourmet strategy in which only the highest utility parts are selected, and a reverse utility approach wherein low-value portions were consistently left behind at a site.

TABLE 5. — The distribution of impact cones on skeletal elements in level 4 and level 5 at the Croxton site.

Skeletal element	Mammalia, indeterminate		Mammalia, large		Artiodactyla, medium		Cervidae, medium		Rangifer tarandus Linnaeus, 1758	
	Level 4	Level 5	Level 4	Level 5	Level 4	Level 5	Level 4	Level 5	Level 4	Level 5
Innominate	–	–	–	–	–	–	–	–	–	1
Humerus, shaft fragment	–	–	–	–	–	–	–	–	16	9
Radius, shaft fragment	–	–	–	–	–	–	–	–	1	–
Femur, shaft fragment	–	–	–	–	–	–	–	–	5	3
Tibia, shaft fragment	–	–	–	–	–	–	–	–	14	9
Long bone shaft fragment	8	1	5	3	30	5	–	–	–	–
Metacarpal, shaft fragment	–	–	–	–	–	–	–	–	5	4
Metatarsal, shaft fragment	–	–	–	–	–	–	–	–	11	6
Metapodial, shaft fragment	–	–	–	–	–	–	1	–	–	–
First phalanx, fragment	–	–	–	–	–	–	–	–	1	–
Total	8	1	5	3	30	5	1	–	53	32

Results for the Croxton 1989 sample show a pattern in the relationship between the MGUI and %MAU (Fig. 5) that in Binford's (1978) terms is most similar to either an unbiased strategy in which a straight line of data points extends from the lower left to upper right of the chart, indicating an indiscriminate subsistence pattern on the bulk to gourmet continuum; or a gourmet pattern in which the line of data points curves to the lower-right, indicating that highest-utility elements are represented. Within the site, levels 4 and 5 produced indiscriminate subsistence patterns on this continuum.

These interpretations are further clarified by following non-linear chart characterizations by Beaver (2004). The levels 4 and 5 charts resemble a reverse bulk lower-left triangular plot in which low general utility is necessary but not sufficient to explain skeletal element representation. This pattern is supported in part by the relative abundance of mandibles, metacarpals and metatarsals that have low general utility. The 1989 correlation shows a triangular scatter toward the lower-right corner of the graph. This indicates a relationship between the two variables in which mostly high general utility elements are represented and several high-utility elements are also not well-represented. General utility was a limiting factor in the bone assemblage but was not the only factor causing variation. These results are consistent with human transport of higher value caribou body parts to area J from the lakeside or off-site. Transport within area J of caribou portions that are low in general utility but higher in grease and marrow utility also influenced skeletal part representations at Croxton.

## DISCUSSION

### SUBSISTENCE IN CONTEXT

Caribou was the main subsistence focus of prehistoric occupants at the Croxton site. Faunal results show that people relied primarily on these animals and may have supplemented their diets with small numbers of wild birds, fish, and small mammals such as beavers. Incised bird long bones show these elements were probably raw material for the manufacture

TABLE 6. — Croxton site: ANOVA results at the 95% confidence level showing no significant difference of size in caribou-sized bone fragment and caribou humeri fragment across levels. Abbreviations: **df**, degrees of freedom; **F**, F-statistic; **p value**, probability value; **F crit.**, critical value of F.

Caribou-sized bone fragment				
	Level 2	Level 3	Level 4	Level 5
Count	9	34	780	313
Arithmetic mean	51.73	47.08	50.70	55.37
ANOVA	df 3	F 1.40	p value 0.24	F crit. 2.61
Caribou humeri fragment				
	Level 2	Level 3	Level 4	Level 5
Count	–	3	30	23
Arithmetic mean	–	67.27	60.11	57.25
ANOVA	df 2	F 0.40	p value 0.67	F crit. 3.17

of needles. Birds are a known part of Ipiutak subsistence (Moss & Bowers 2007) and although in small numbers at Croxton may also have contributed to diets there. Fish were caught occasionally for consumption at this lakeside location. Beaver elements are two incisor teeth that were for tools or ornamentation and may have been carried to this site from a woodland area typical of these animal's habitat. Where available, beavers are likely also have been a food source. Very small rodents were probably incorporated into the assemblage as a result of natural deaths. Canids are present in Ipiutak levels and may represent domesticates that served as pets and work dogs.

Primary dependence on caribou at Croxton was motivated by availability. As a cold adapted species with an extensive northern range (Geist 1998), caribou would have been well-suited to the cool climate of the Brooks Range in the middle to late Holocene (Oswald *et al.* 1999; Clegg & Hu 2010), and are the dominant ungulate taxa on that landscape today. Although people at the Croxton site may or may not have incorporated caribou into their diets in the same exact proportions as these animals occurred, the high relative abundance of caribou in the faunal sample likely reflects local accessibility of these animals.

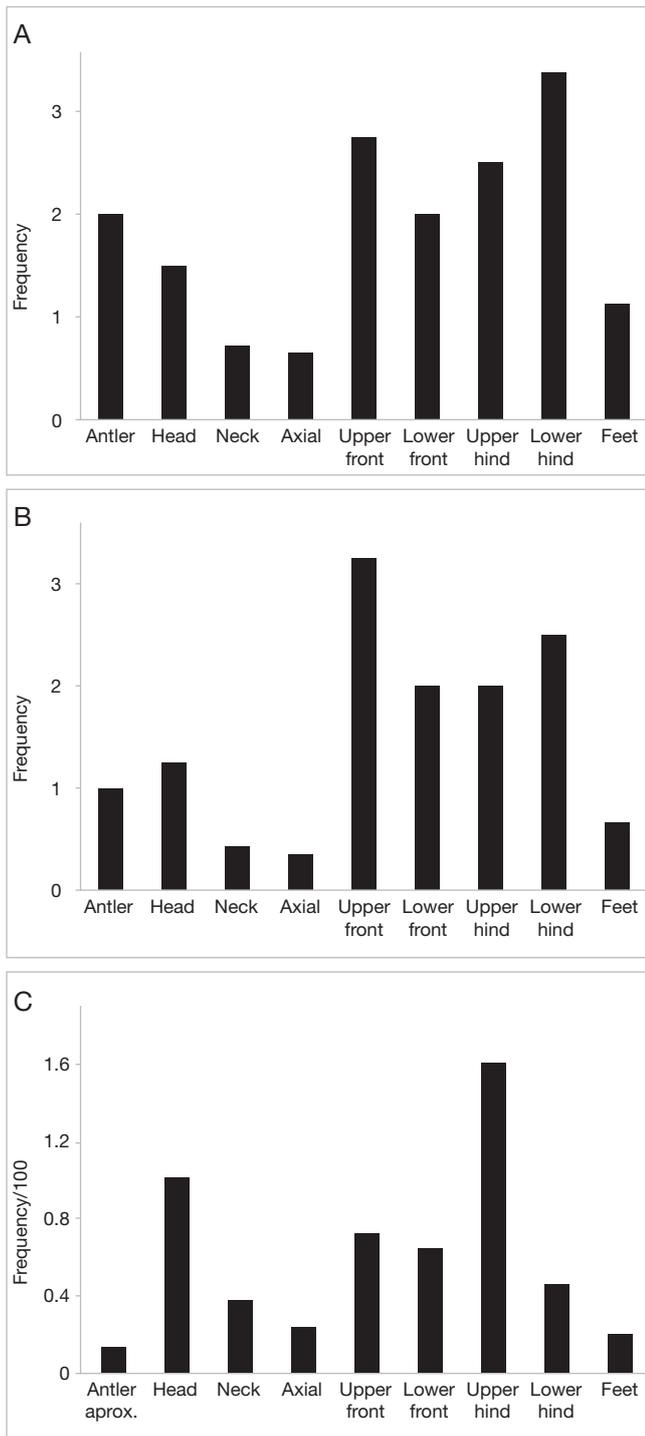


FIG. 3. — Croxton site anatomical portion frequencies. **A**, Level 4; **B**, Level 5; **C**, reassessed data from the 1989 faunal sample. The vertical axis indicates the frequencies of standardized skeletal elements.

Ipiutak people were highly mobile and occupied coastal and inland locations (Anderson 1984). Inland excursions focused on caribou hunting that occurred across the Brooks Range at least as far east as the Bateman site at Itkillik Lake (Mason 2016). High relative abundance of caribou at Croxton is consistent with this aspect of Ipiutak subsistence. The inland



FIG. 4. — Split caribou (*Rangifer tarandus* (Linnaeus, 1758)) right metatarsal with impacts on opposing surfaces. After being split and discarded, the bone surface took on a brown stain during burial in humic soil. Scale bar: 10 cm.

Ipiutak focus on caribou is also evidenced in faunal remains at the Onion Portage site (Anderson 1988) and in fragmented caribou remains recovered at the summer through fall encampment at Anaktuvuk Pass (Mills *et al.* 2005). Both locations are major caribou transit intercepts and indicate procurement and processing of these animals as a primary nutrient source. Coastal Ipiutak sites are characterized by abundant pinnipeds including ringed seals (*Pusa hispida* Schreber, 1775) and bearded seals (*Erignathus barbatus* Erxleben, 1777), and walrus (*Odobenus rosmarus* (Linnaeus, 1758)), with caribou as a minor contributor to specimen counts. In the Deering area at Kotzebue Sound, seasonally available migratory birds including murre (*Uria* Brisson, 1760) also contributed significantly to diets (Moss & Bowers 2007). Together the faunal record indicates that Ipiutak hunters occupied specific locations in diverse environmental settings to procure resources that were seasonally abundant. It is in this framework that caribou were the main subsistence focus at the Croxton site.

Denbigh subsistence is best known from the faunal record at the 4000 year old Matcharak Lake site in central Brooks Range, Alaska (Tremayne 2011). Caribou are abundant in the Matcharak assemblage, with smaller relative contributions to diets from Dall's sheep, small mammals including Arctic ground squirrel (*Spermophilus parryi* Richardson, 1825) and Alaska marmot (*Marmota broweri* Hall & Gilmore, 1934), migratory birds such as ptarmigan (*Lagopus* sp. Brisson, 1760), and fish including Arctic grayling (*Thymallus arcticus* Pallas, 1776) and burbot (*Lota lota* (Linnaeus, 1758)). Seasonal indicators suggest spring through fall occupation for activities

TABLE 7. — Spearman's Rho results for utility indices on caribou-sized bones from the Croxton site showing significant positive correlations with marrow and grease utility. Abbreviations: **CT**, computed tomography; **MGUI**, modified general utility index. Numbers in bold are statistically significant at alpha level 0.05.

	Level 4	Level 5	1989
Meat utility	0.2078	0.5105	0.4082
Marrow utility	<b>0.0007</b>	<b>0.0034</b>	0.7656
Grease utility	<b>0.0067</b>	<b>0.0047</b>	0.2021
MGUI	0.6174	0.5075	<b>0.0145</b>
CT	0.5929	0.3486	0.7991

focused on caribou hunting and processing, possibly including bone marrow and grease use. Fishing as a minor component of Denbigh subsistence is also indicated by the presence of a notched sinker at Onion Portage and by fish scales in middens at Punyik Point (Anderson 1984). The contemporary faunal record shows that caribou were the main prey animals sought by inland Denbigh hunters.

Anatomical portion representation and taphonomic and statistical results with utility indices are complementary in this study and support an enduring tradition of marrow and grease procurement from caribou in northern Alaska. Nutritional sources from these animals are evidenced in cut marks signaling butchery and meat removal that is consistent with the tendency toward portions high in general utility in area J. Significant correlations for marrow utility correspond with impact cones that evidence breaking of long bones for marrow removal. Positive grease utility results, many bone fragments and some very small burnt shards, as well as susceptibility to bone surface dissolution are consistent with bones having been processed for grease. Anatomical profiles emphasize the presence of upper and lower leg portions and support these inferences. That partitioning caribou in terms of general nutritional value and marrow and grease processing are found in the same region as Binford's ethnographic Nunamiut study suggests continuity from Denbigh through modern times in the presence of these economic approaches.

Croxton site inhabitance selected caribou portions that are high in general utility and these animals were also targeted for specific nutrients as marrow and grease, which expresses two different approaches to caribou use that are linked with the periodic nature of availability. During the middle and late Holocene in northern Alaska, prehistoric occupation at the Croxton site focused on procurement and processing of caribou during spring through autumn (Gerlach & Hall 1988). These animals are likely to have supported the immediate needs of site inhabitants as well as a requirement for food storage in anticipation of caribou herds dispersal south in winter (see Skoog 1968 for a modern example). Day to day food needs probably included a range of nutritional values in a context of relative abundance and food security as animals were hunted and processed during warm months of the year. Requirements for delayed consumption as stored food needed between times of lower food availability are likely to have focused on meat preservation and on marrow and grease processing. Marrow and grease from bones contain fatty acids that are conducive

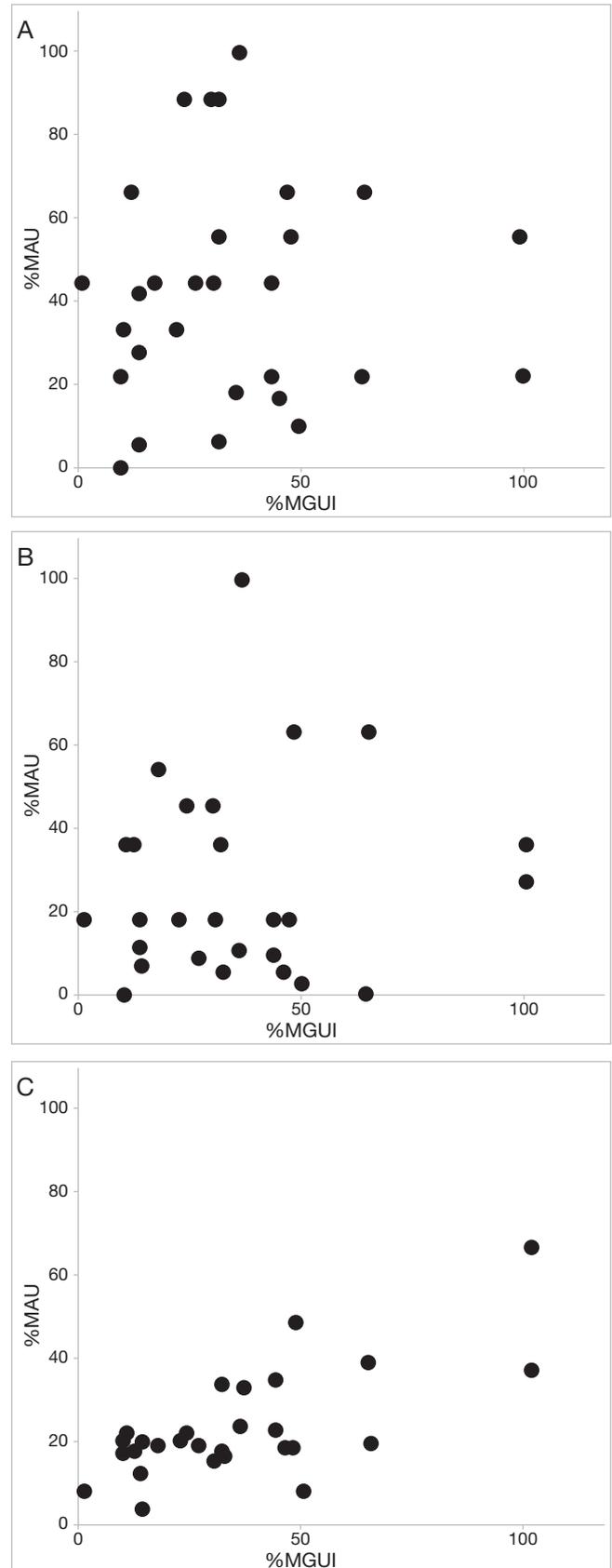


FIG. 5. — Utility curve diagrams of %MGUI and %MAU for Croxton site faunal samples. **A**, level 4; **B**, level 5; **C**, reassessed 1989 sample.

to long-term storage and transport (Manne 2014), have high caloric content, and would have been necessary in northern prehistoric hunter-gatherer diets to alleviate nutritional stress that can result from a primary dependence on lean meat in terrestrial mammals. Mitigation of such stress through consumption of marrow and grease may have been particularly necessary during winter, when fresh nutrient sources typically dwindle (Speth & Spielmann 1983; Enloe 1993; Morin 2007). Caribou portions high in general utility in the large faunal sample from area J at Croxton reflect the generalized food procurement and processing focus of site inhabitants, while concentrations of marrow and grease processing debris attest to these specific nutritional uses that are likely to have, at least in part, been stored for later consumption.

#### AGGREGATION EFFECTS & CARIBOU PROCESSING

Significant statistical correlations with utility indices were found for within-bone nutrients in this study but were not found in the larger sample of caribou bones studied previously (Gerlach 1989). The faunal aggregates available for analyses may be at least partially to blame. In the previous study the faunal sample was derived from numerous excavations units across the site that comprised the Ipiutak cultural component. Though my reassessment of the sample with a different counting methodology found a significant result with MGUI, the 1989 analyses did not find statistically significant correlations with meat, MGUI, marrow or grease indices even though taphonomic characteristics of the assemblage, including numerous cut and percussion marks as well as burnt and fragmented bones, suggested economic uses. To explain the lack of significant statistical correlations, Gerlach (1989) rightly pointed to the potential effects of time-averaging on the bone assemblage that accumulated during a time in which caribou hunting probably took place both at the lakeside, resulting in whole animals at the site, as well as further afield, and resulted in transport of anatomical portions that made specific subsistence activities difficult to discern statistically in the temporally coarse faunal sample with complex depositional and taphonomic histories.

In addition to time-averaging, the spatial position of faunal aggregates chosen for analysis are likely to have influenced the outcomes of utility analyses. MNE values are the basis of utility analyses and, like other derived analytical units such as MNI (Grayson 1984) and MAU (Lyman 1994), can be expected to suffer from difficulties associated with the lumping and splitting of faunal assemblages in which analytical results may vary when performed on different faunal aggregates. The question of how to split or lump a faunal assemblage for analysis is always addressed by the analyst and often results in aggregates that reflect whole cultural components so that something can be said about an archaeological culture. However, in some cases, and notwithstanding potential problems associated with small sample sizes (Faith & Gordon 2007), analyses of faunal aggregates smaller than the culture component level can reveal subsistence practices that are statistically imperceptible in analyses of larger aggregates. This may be particularly useful when designing utility analyses at archaeological sites where

whole animals were often present or a full range of carcass processing and discard activities are likely to have been performed. At such localities, specific economic uses as meat, marrow or grease may become difficult to detect statistically in a site-wide faunal sample. Alternative analytical units such as those comprised of faunal remains from well-defined house features or around hearths may provide reasonable analytical units. Unfortunately, the availability of such features tends to be limited by the affordances of the archaeological site under investigation, and even where available only those processing and discard activities that required routine sectioning off of portions of animals to different areas of a site are likely to be visible archaeologically.

At the Croxton site, statistical comparisons between utility indices and caribou remains from the entire Ipiutak component may have suffered from the aforementioned problem. The excavation units from which the 1989 faunal sample was derived covered much of the surface area of this large site. Its lakeside location and site function suggest that caribou carcasses may often have entered the site whole and faunal aggregate spanned millennia. No convenient alternative analytical units such as well-defined house features were obvious at this site, so the 1989 analysis was performed on the entire Ipiutak component fauna. The result was that statistical analyses with utility indices gave no correlations even though taphonomic results did support specific marrow and grease uses by site occupants. It is likely that the 1989 faunal sample was amassed spatially and temporally to a greater extent than allowed for the detection of these specific subsistence practices.

Analyses of a within-site faunal aggregate in the present study did produce significant statistical results for marrow and grease utility. The AD 2000 excavations found a bone-rich deposit and hearth features that, together with taphonomic evidence of food processing and skeletal elements emphasizing caribou leg portions, support that the faunal sample was drawn from remnant activity areas containing bone deposits from marrow and grease processing. Tool manufacturing activities may also have taken place in this area of the site based on the presence of bird bone needle preforms, beaver incisors, and the relative abundance of antler in level 4. Although this outcome was fortuitous, as this part of the site was not targeted in excavation to find an activity area, the results of this study are encouraging in terms of potential for identifying additional spatial organization as stationed activities and discard, which is a reasonable expectation of sites in this region (Binford 1983; O'Connell 1987).

#### CONCLUSION

Prehistoric subsistence practices at the Croxton archaeological site were studied through species identifications, skeletal part frequencies, as well as taphonomic and utility analyses of faunal remains. Results support several conclusions. Human subsistence activities were a primary source of archaeological faunal accumulations. Caribou were a principal food source and are likely to have been a main attractor for prehistoric

occupation at this site as people selectively hunted these animals from in and around Tukuto Lake. Taphonomic indicators including cuts and percussion marks on long bones, burnt and fragmented specimens, and susceptibility to surface degradation indicate caribou were processed for high-value portions including within bone nutrients. Anatomical portion representations and statistical results with utility indices support these observations. Caribou portions high in general utility were brought to the upper terrace at area J. Leg portions were also partitioned into parts for specific nutrients as marrow and grease, and these were relocated within the site for processing and discard.

These results is that the bone sample aggregates chosen for analyses have influenced statistical results in this study and are also likely to have influenced statistical outcomes in the previous faunal study, highlighting a potentially problematic aspect of such analyses. Analysts must make decisions about which samples are appropriate units of study for the objective at hand and based on available information. These decisions do not have to be restricted to the largest available samples or entire archaeological cultures. If well-reasoned, smaller units of analysis can be appropriate and may reveal aspects of past behaviours that are inaccessible in studies of larger faunal aggregates.

Results herein indicate no substantial differences in caribou utilization across levels and cultural components at Croxton. There are more similarities than differences in the characteristics of faunal remains in level 4, which lies in the Ipiutak component, and level 5, which also contains Denbigh material. There is no significant difference in caribou-sized fragments across levels and skeletal part frequencies and taphonomic characteristics of bone specimens are consistent throughout the assemblage. Both levels show caribou as the most important resource and provide support for marrow and grease utilization. Local longevity in these subsistence practices is further underscored by comparisons with utility indices that were developed nearby with the Nunamiut at Anaktuvuk Pass that demonstrate marrow and grease utilization also persist in modern times.

The proximity of the Croxton site and Anaktuvuk Pass along the north slope of the Brooks Range encourages examination of subsistence practices in this specific region. Caribou have, however, long been a subsistence resource of human groups throughout much of the Northern Hemisphere, making analytical approaches to the study of these animals potentially broadly applicable. In whichever region or species of interest, the analytical power of utility indices rests in their use as economic optimization models that can be examined in terms of their efficacy for predicting human subsistence behaviours.

### Acknowledgements

Funding was provided to the author through an NSERC award and from the University of Arizona, School of Anthropology, Louie and Frances-Fera Schiffer Scholarship (archaeology). Thank you Mary Stiner for asking me to analyze the Croxton faunal sample and for providing access to the comparative

collection in the Paleolithic Laboratory at the School of Anthropology, University of Arizona, and to Josh Reuther at the University of Alaska for initiating the process with her. Barnet Pavao Zuckerman facilitated my use of comparative collection at the Stanley J. Olsen Laboratory, Arizona State Museum. I appreciate the comments I received from the reviewers and editors of this manuscript.

### REFERENCES

- ANDERSON P. M. 1984. — Prehistory of North Alaska, in DUMOND D. (ed.), *Handbook of North American Indians. 5, Arctic*. Smithsonian Institution, Washington: 80-93.
- ANDERSON D. D. 1988. — Onion Portage: the archaeology of a stratified site from the Kobuk River, northwest Alaska. *Anthropological Papers of the University of Alaska* 22 (1-2): 1-16.
- BANFIELD A. W. F. 1951. — *The Status, Ecology, and Utilization of the Continental Barren-Ground Caribou* (*Rangifer arcticus arcticus*). PhD dissertation, University of Michigan, Ann Arbor, 338 p.
- BEAVER J. E. 2004. — Identifying necessity and sufficiency relationships in skeletal-part representation using fuzzy-set theory. *American Antiquity* 69 (1): 131-140. <https://doi.org/10.2307/4128351>
- BEHRENSMEYER A. K. 1978. — Taphonomic and ecologic information from bone weathering. *Paleobiology* 4 (2): 150-162. <https://doi.org/10.1017/S0094837300005820>
- BINFORD L. R. 1978. — *Nunamiut Ethnoarchaeology*. Academic Press, New York, 509 p.
- BINFORD L. R. 1981. — *Bones: Ancient Men and Modern Myths*. Academic Press, New York, 320 p.
- BINFORD L. R. 1983. — People and their lifespaces, in BINFORD L. R. (ed.), *In Pursuit of the Past: Decoding the Archaeological Record*. Thames and Hudson, New York: 144-192.
- BLUMENSCHINE R. J. & CARO T. M. 1986. — Unit flesh weights of some East African bovids. *African Journal of Ecology* 24 (4): 273-286. <https://doi.org/10.1111/j.1365-2028.1986.tb00371.x>
- BOUCHUD J. 1966. — *Essai sur le Renne et climatologie du Paléolithique moyen et supérieur*. Imprimerie Mague, Périgueux, 300 p.
- BRIDAULT A., CHAIX L., PION G., OBERLIN C., THIEBAULT S. & ARGANT J. 2000. — Position chronologique du Rennes (*Rangifer tarandus* L.) à la fin du Tardiglaciaire dans les Alpes du Nord françaises et le Jura méridional, in PION G. (éd.), *Le Paléolithique supérieur récent: nouvelles données sur le peuplement et l'environnement. Actes de la table ronde de Chambéry, 12-13 mars 1999*. Société préhistorique française, Paris: 47-57. (Coll. Mémoire de la Société préhistorique française; 28).
- BRINK J. W. 1997. — Fat content in leg bones of *Bison bison* and applications to archaeology. *Journal of Archaeological Science* 24 (3): 259-274. <https://doi.org/10.1006/jasc.1996.0109>
- BRONK RAMSEY C. 2009. — Bayesian analysis of radiocarbon dates. *Radiocarbon* 51 (1): 337-360. <https://doi.org/10.1017/S0033822200033865>
- BROUGHTON J. M. 1999. — *Resource Depression and Intensification during the Late Holocene, San Francisco Bay: Evidence from the Emeryville Shellmound*. University of California Press, Berkeley, 158 p.
- BUNN H. T., BARTRAM L. E. & KROLL E. M. 1988. — Variability in bone assemblage formation from Hadza hunting, scavenging, and carcass processing. *Journal of Anthropological Archaeology* 7 (4): 412-457. [https://doi.org/10.1016/0278-4165\(88\)90004-9](https://doi.org/10.1016/0278-4165(88)90004-9)
- BURCH E. S. 1972. — The caribou/wild reindeer as a human resource. *American Antiquity* 37 (3): 339-368. <https://doi.org/10.2307/278435>
- CHURCH R. & LYMAN R. L. 2003. — Small fragments make small differences in efficiency when rendering grease from fractured artiodactyl bones by boiling. *Journal of Archaeological Science* 30 (8): 1077-1084. [https://doi.org/10.1016/S0305-4403\(03\)00010-4](https://doi.org/10.1016/S0305-4403(03)00010-4)

- CLEGG B. F. & HU F. S. 2010. — An oxygen-isotope record of Holocene climate change in the south-central Brooks Range, Alaska. *Quaternary Science Reviews* 29 (7-8): 928-939. <https://doi.org/10.1016/j.quascirev.2009.12.009>
- DUMOND D. E. 1984. — Prehistory, summary, in DUMOND D. E. (ed.), *Handbook of North American Indians. 5, Arctic*. Smithsonian Institution, Washington: 72-79.
- ENLOE J. G. 1993. — Ethnoarchaeology of marrow cracking: implications for the recognition of prehistoric subsistence organization, in HUDSON J. (ed.), *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations, Southern Illinois University, Carbondale: 82-97. (Coll. Occasional Papers; 21).
- ENLOE J. G. 2003. — Acquisition and processing of reindeer in the Paris Basin, in COSTAMAGNO S. & LAROUANDIE V. (eds), *Zooarchaeological insights into Magdalenian lifeways: Acts of the XIV<sup>th</sup> UISPP Congress*, University of Liège, Belgium, 2-8 September 2001. *BAR International Series* 1144: 23-31.
- FAITH T. J. & GORDON A. D. 2007. — Skeletal element abundances in archaeofaunal assemblages: economic utility, sample size, and assessment of carcass transport strategies. *Journal of Archaeological Science* 34 (6): 872-882. <https://doi.org/10.1016/j.jas.2006.08.007>
- FERNÁNDEZ-JALVO Y. & ANDREWS P. 2016. — *Atlas of Taphonomic Identifications: 1001+ Images of Fossil and Recent Mammal Bone Modification*. Springer, New York, 359 p. (Coll. Vertebrate Paleobiology and Paleoanthropology). <https://doi.org/10.1007/978-94-017-7432-1>
- FRIESEN T. M. & STEWART A. 2013. — To freeze or to dry: seasonal variability in caribou processing and storage in the barrenlands of Northern Canada. *Anthropozoologica* 48 (1): 89-109. <https://doi.org/10.5252/az2013n1a5>
- GEIST V. 1998. — *Deer of the World: Their Evolution, Behavior, and Ecology*. Stackpole Books, Mechanicsburg PA, 421 p.
- GERLACH S. C. 1989. — *Models of Caribou Exploitation, Butchery, and Processing at the Croxton Site, Tukuto Lake, Alaska*. Ph.D. dissertation, Department of Anthropology, Brown University, Providence, 532 p.
- GERLACH S. C. & HALL E. S. JR. 1988. — The later prehistory of northern Alaska: the view from Tukuto Lake, in SHAW R. D., HARRITT R. K. & DUMOND D. E. (eds), *The Late Prehistoric Development of Alaska's Native People*. Alaska Anthropological Association, Anchorage AK: 137-145. (Coll. Aurora; 4).
- GERLACH S. C. & MASON O. K. 1992. — Calibrated radiocarbon dates and cultural interaction in the Western Arctic. *Arctic Anthropology* 29 (1): 54-81.
- GIFFORD-GONZALEZ D. P. 1993. — Gaps in ethnoarchaeological research on bone, in HUDSON J. (ed.), *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations, Southern Illinois University, Carbondale: 181-199. (Coll. Occasional Paper; 21).
- GOTFREDSEN A. B. 2010. — Faunal remains from the Wollaston Forland – Clavering Ø region, Northeast Greenland – Thule culture subsistence in a high Arctic polynya and ice-edge habitat. *Geografisk Tidsskrift* 110: 175-200. <https://doi.org/10.1080/00167223.2010.10669506>
- GORDON B. C. 1990. — World *Rangifer* communal hunting, in DAVIS L. B. & REEVES B. O. K. (eds), *Hunters of the Recent Past*. Unwin Hyman, London: 277-303.
- GRAYSON D. K. 1984. — *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Academic Press, New York, 202 p.
- GRAYSON D. K., DELPECH D., RIGAUD J.-P. & SIMEC J. F. 2001. — Explaining the development of dietary dominance by a single ungulate taxon at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 28 (2): 115-125. <https://doi.org/10.1006/jasc.2000.0556>
- HALL E. R. 1981. — *The Mammals of North America. 2<sup>nd</sup> ed.* John Wiley and Sons, New York, 717 p.
- HOFFECCKER J. F., KUZ'MINA I. E., SYROMYATNIKOVA E. V., ANIKOVICH M. V., SINITSYN A. A., POPOV V. V. & HOLLIDAY V. T. 2010. — Evidence for kill-butcher events of early Upper Paleolithic age at Kostenki, Russia. *Journal of Archaeological Science* 37 (5): 1073-1089. <https://doi.org/10.1016/j.jas.2009.12.008>
- INGSTAD H. 1954. — *Nunamiut: Among Alaska's Inland Eskimos*. Allen & Unwin, London, 254 p.
- JACKSON L. J. & THACKER P. T. 1997. — *Caribou and Reindeer Hunters of the Northern Hemisphere*. Avebury Press, London, 258 p.
- KLEIN R. G. & CRUZ-URIBE K. 1984. — *The Analysis of Animal Bones from Archeological Sites*. Chicago University Press, Chicago & London, 266 pp.
- KUNTZ D. & COSTAMAGNO S. 2011. — Relationships between reindeer and man in southwestern France during the Magdalenian. *Quaternary International* 238 (1-2): 12-24. <https://doi.org/10.1016/j.quaint.2010.10.023>
- LAM Y. M., CHEN X. & PEARSON O. M. 1999. — Intertaxonomic variability in patterns of bone density and the differential representation of bovid, cervid, and equid elements in the archaeological record. *American Antiquity* 64 (2): 343-362. <https://doi.org/10.2307/2694283>
- LEECHMAN D. 1951. — Bone grease. *American Antiquity* 16 (4): 355-356. <https://doi.org/10.2307/276988>
- LYMAN R. L. 1985. — Bone frequencies: differential transport, *in situ* destruction, and the MGUI. *Journal of Archaeological Science* 12 (3): 221-236. [https://doi.org/10.1016/0305-4403\(85\)90022-6](https://doi.org/10.1016/0305-4403(85)90022-6)
- LYMAN R. L. 1994. — *Vertebrate Taphonomy*. Cambridge University Press, Cambridge UK, 524 p.
- LYMAN R. L., SAVELLE J. M. & WHITRIDGE P. 1992. — Derivation and application of a meat utility index for phocid seals. *Journal of Archaeological Science* 19 (5): 531-555. [https://doi.org/10.1016/0305-4403\(92\)90027-Z](https://doi.org/10.1016/0305-4403(92)90027-Z)
- MAGNIEZ P., MOIGNE A.-M., TESTU A. & LUMLEY H. DE 2013. — Biochronologie des mammifères quaternaires: apport des cervidés du site pléistocène moyen de la Caune de l'Arago (Tautavel, Pyrénées-Orientales, France). *Quaternaire* 24 (4): 477-502. <https://doi.org/10.4000/quaternaire.6830>
- MANNE T. 2014. — Early Upper Paleolithic bone processing and insights into small-scale storage of fats at Vale Boi, southern Iberia. *Journal of Archaeological Science* 43: 111-123. <https://doi.org/10.1016/j.jas.2013.12.003>
- MAREAN C. W., YOSHIKO A., NILSSEN P. J. & STONE E. C. 2001. — Estimating the minimum number of skeletal elements (MNE) in zooarchaeology: a review and a new image-analysis approach. *American Antiquity* 66 (2): 333-348. <https://doi.org/10.2307/2694612>
- MASON O. K. 2016. — From the Norton culture to the Ipiutak cult in northwest Alaska, in FRIESEN M. & MASON O. K. (eds), *The Oxford Handbook of Prehistoric Arctic*. Oxford University Press, Oxford: 443-467. <https://doi.org/10.1093/oxfordhb/9780199766956.013.52>
- MELLARS P. A. 2004. — Reindeer specialization in the early Upper Palaeolithic: the evidence from south west France. *Journal of Archaeological Science* 31 (5): 613-617. <https://doi.org/10.1016/j.jas.2003.10.010>
- MELTZER D. J. 1988. — Late Pleistocene human adaptations in eastern North America. *Journal of World Prehistory* 2 (1): 1-52. <https://doi.org/10.1007/BF00975121>
- METCALFE D. & JONES K. T. 1988. — A reconsideration of animal body-part utility indices. *American Antiquity* 53 (3): 486-504. <https://doi.org/10.2307/281213>
- MILLS R. O., GERHACH S. C. & BOWERS P. M. 2005. — Stability and change in the use of place at the Kame Terrace site, Anaktuvuk Pass, Alaska. *Anthropological Papers of the University of Alaska* 4 (1): 27-58.
- MORIN E. 2007. — Fat composition and Nunamiut decision-making: a new look at the marrow and bone grease indices. *Journal of*

- Archaeological Science* 34 (1): 69-82. <https://doi.org/10.1016/j.jas.2006.03.015>
- MOSS M. L. & BOWERS P. M. 2007. — Migratory bird harvest in northwestern Alaska: a zooarchaeological analysis of Ipiutak and Thule occupations from the Deering Archaeological District. *Arctic Anthropology* 44 (1): 37-50. <https://doi.org/10.1353/arc.2011.0055>
- NUTTALL M. 2005. — *Encyclopedia of the Arctic*. Routledge, London, 2278 p.
- O'CONNELL J. F. 1987. — Alyawara site structure and its archaeological implications. *American Antiquity* 52 (1): 74-108. <https://doi.org/10.2307/281061>
- O'CONNELL J. F., BLURTON JONES N. & HAWKES K. 1988. — Hadza hunting, butchering, and bone transport and their archaeological implications. *Journal of Anthropological Research* 44 (2): 113-161. <https://doi.org/10.1086/jar.44.2.3630053>
- O'CONNELL J. F. & MARSHALL B. 1989. — Analysis of kangaroo body part transport among the Alyawara of Central Australia. *Journal of Archaeological Science* 16 (4): 393-405. [https://doi.org/10.1016/0305-4403\(89\)90014-9](https://doi.org/10.1016/0305-4403(89)90014-9)
- O'SHEA J. M., LEMKE A. K., SONNENBURG E. P., REYNOLDS R. G. & ABBOTT B. D. 2014. — A 9,000-year-old caribou hunting structure beneath Lake Huron. *PNAS* 111 (19): 6911-6915. <https://doi.org/10.1073/pnas.1404404111>
- OSWALD W. W., BRUBAKER L. B. & ANDERSON P. M. 1999. — Late Quaternary vegetational history of the Howard Pass area, northwestern Alaska. *Canadian Journal of Botany* 77 (4): 570-581. <https://doi.org/10.1139/b99-027>
- OUTRAM A. & PETER R. C. 1997. — Meat and marrow utility indices for horse (*Equus*). *Journal of Archaeological Science* 25 (9): 839-849. <https://doi.org/10.1006/jasc.1997.0229>
- PASDA K. & ODGAARD U. 2011. — Nothing is wasted: The ideal “nothing is wasted” and divergence in past and present among caribou hunters in Greenland. *Quaternary International* 238 (1-2): 35-43. <https://doi.org/10.1016/j.quaint.2010.12.036>
- REIMER P. J., BARD E., BAYLISS A., BECK J. W., BLACKWELL P. G., BRONK RAMSEY C., BUCK C. E., CHENG H., EDWARDS R. L., FRIEDRICH M., GROOTES P. M., GUILDERTSON T. P., HAFLIDASON H., HAJDAS I., HATTÉ C., HEATON T. J., HOFFMANN D. L., HOGG A. G., HUGHEN K. A., KAISER K. F., KROMER B., MANNING S. W., NIU M., REIMER R. W., RICHARDS D. A., SCOTT E. M., SOUTHON J. R., STAFF R. A., TURNEY C. S. M. & VAN DER PLICHT J. 2013. — IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 Years cal BP. *Radiocarbon* 55 (4): 1869-1887. [https://doi.org/10.2458/azu\\_js\\_rc.55.16947](https://doi.org/10.2458/azu_js_rc.55.16947)
- REITZ E. J. & WING E. S. 1999. — *Zooarchaeology*. Cambridge University Press, New York, 560 p.
- REUTHER J. D. & GERLACH S. C. 2005. — Testing the “Dicarb Problem”: a case study from north Alaska. *Radiocarbon* 47 (3): 359-366. <https://doi.org/10.1017/S003382220003513X>
- RIGNAUD J. P. & SIMEK J. 1990. — The last pleniglacial in the south of France (24 000-14 000 years ago), in SOFFER O. & GAMBLE C. (eds), *The world at 18 000 BP. Vol. 1, High Latitudes*. Unwin Hyman, London: 69-86.
- SAVELLE J. M. & FRIESEN M. T. 1996. — An Odontocete (Cetacea) meat utility index. *Journal of Archaeological Science* 23 (5): 713-721. <https://doi.org/10.1006/jasc.1996.0067>
- SKOOG R. 1968. — *Ecology of the Caribou (Rangifer tarandus granti) in Alaska*. Doctoral dissertation, University of California, Berkeley, 699 p.
- SPETH J. D. & SPIELMANN K. A. 1983. — Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology* 2 (1): 1-31. [https://doi.org/10.1016/0278-4165\(83\)90006-5](https://doi.org/10.1016/0278-4165(83)90006-5)
- SPIESS A. 1979. — *Reindeer and Caribou Hunters: an Archaeological Study*. Academic Press, New York, 336 p.
- STINER M. C. 1990. — The use of mortality patterns in archaeological studies of hominid predatory adaptations. *Journal of Anthropological Archaeology* 9 (4): 305-351. [https://doi.org/10.1016/0278-4165\(90\)90010-B](https://doi.org/10.1016/0278-4165(90)90010-B)
- STINER M. C. 1991. — Food procurement and transport by human and non-human predators. *Journal of Archaeological Science* 18 (4): 455-482. [https://doi.org/10.1016/0305-4403\(91\)90038-Q](https://doi.org/10.1016/0305-4403(91)90038-Q)
- STINER M. C. 2002. — On *in situ* attrition and vertebrate body part profiles. *Journal of Archaeological Science* 29 (9): 979-991. <https://doi.org/10.1006/jasc.2001.0798>
- STINER M. C. 2005. — *The faunas of Hayonim Cave, Israel: a 200,000-Year Record of Paleolithic Diet, Demography and Society*. Peabody Museum of Archaeology and Ethnology, Cambridge MA, 330 p. (Coll. American School of Prehistoric Research Bulletin; 48).
- TREMAYNE A. H. 2011. — An analysis of faunal remains from a Denbigh Flint Complex camp at Matcharak Lake, Alaska. *Arctic Anthropology* 48 (1): 33-53. <https://doi.org/10.1353/arc.2011.0108>
- THÉRY-PARISOT I. 2002. — Fuel management (bone and wood) during the lower Aurignacian in the Pataud rock shelter (Lower Palaeolithic, Les Eyzies de Tayac, Dordogne, France): contribution of experimentation. *Journal of Archaeological Science* 29 (12): 1415-1421. <https://doi.org/10.1006/jasc.2001.0781>
- VILLA P., BON F. & CASTEL J. C. 2002. — Fuel, fire, and fireplaces in the Palaeolithic of Western Europe. *The Review of Archaeology* 23 (1): 33-42.
- WEINSTOCK J. 2002. — Reindeer hunting in the Upper Palaeolithic: sex ratios as a reflection of different procurement strategies. *Journal of Archaeological Science* 29 (4): 365-377. <https://doi.org/10.1006/jasc.2002.0716>
- WILSON D. & REEDER D. M. 2005. — *Mammal Species of the World: A Taxonomic and Geographic Reference, 3rd edition*. Johns Hopkins University Press, Baltimore MD, 2142 p.
- YELLEN J. E. 1977. — Cultural patterning in faunal remains: evidence from the !Kung bushmen, in INGERSOLL D., YELLEN J. E. & MACDONALD W. (eds), *Experimental Archeology*. Columbia University Press, New York: 271-331.

Submitted on 25 April 2018;  
accepted on 27 August 2018;  
published on 22 March 2019.